January 1999 Vol. 23 No. 1

TECH BRIEFS

ENGINEERING SOLUTIONS FOR DESIGN & MANUFACTURING

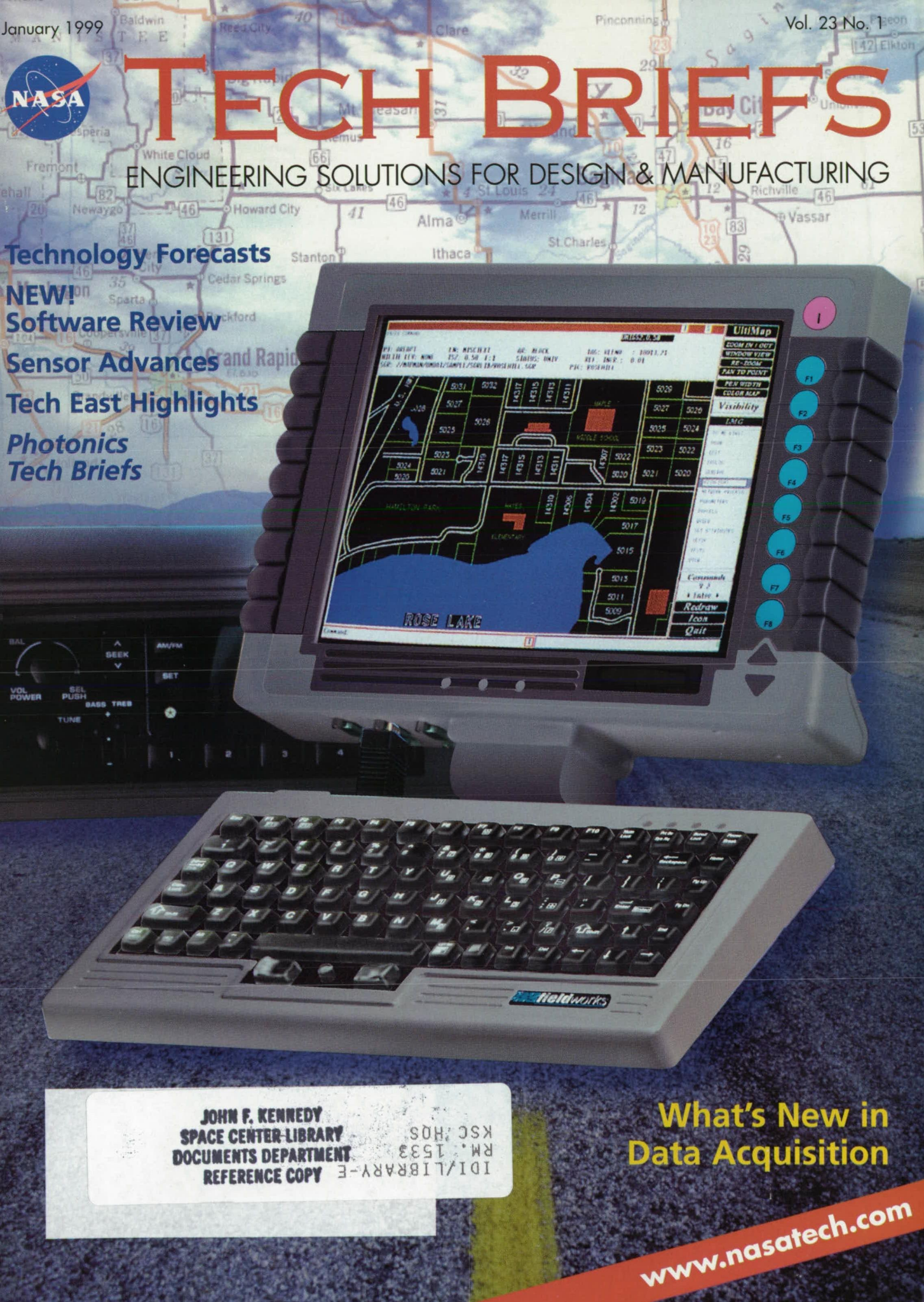
Technology Forecasts

NEW! Software Review

Sensor Advances

Tech East Highlights

Photonics Tech Briefs



What's New in Data Acquisition

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Data Acquisition News

MEASUREMENT READY™ DATA ACQUISITION FROM NATIONAL INSTRUMENTS VOL. 2, NO. 3

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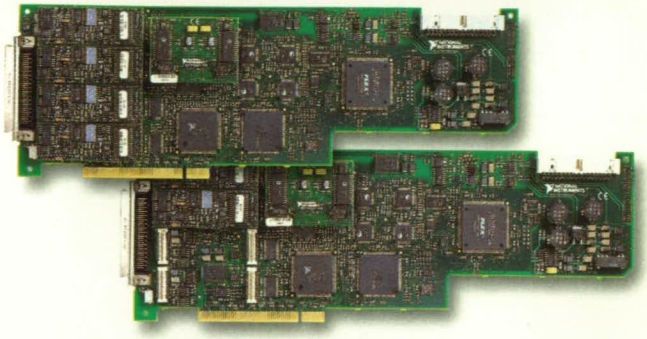
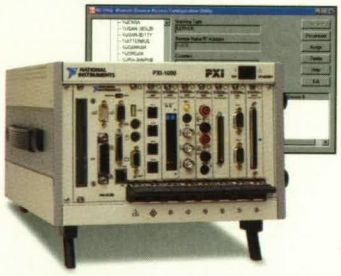
* Typical rates with the PCI-6110E or PCI-6111E



Call for information on performing high-speed data logging and disk streaming with E Series DAQ boards from National Instruments.

Ethernet Measurement Systems

Take measurements over the Ethernet using data acquisition products from National Instruments.



- Perform remote monitoring and control
- Up to seven instrument modules per node
- Seamless integration with application software
- Leverage off existing network infrastructures
- Wide variety of DAQ and signal conditioning hardware

Connect Any Sensor to Your PC

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- RTDs
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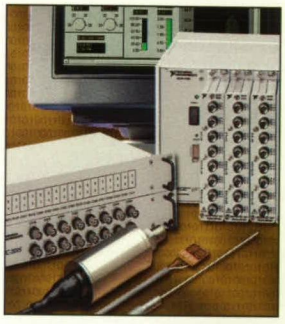

Motion Control for PXI™/CompactPCI

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The new 4-axis stepper motor controllers for PXI/CompactPCI, offering open-loop or closed-loop capabilities, join our FlexMotion™ and ValueMotion™ servo and stepper product lineup.

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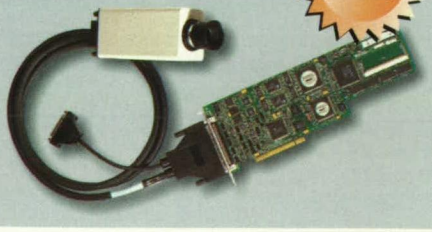

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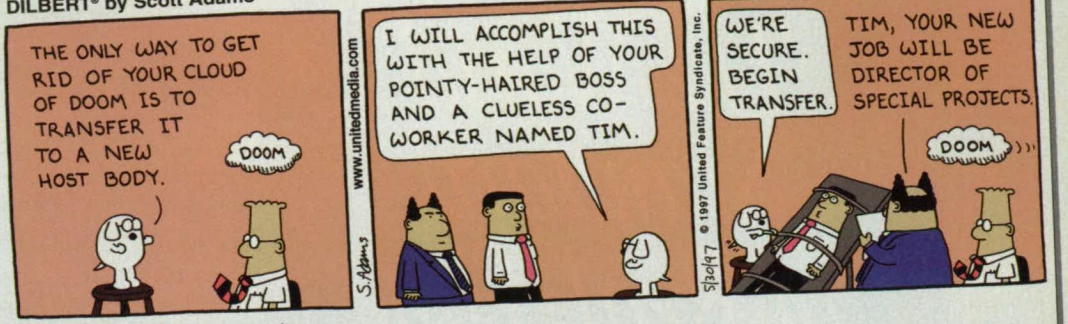

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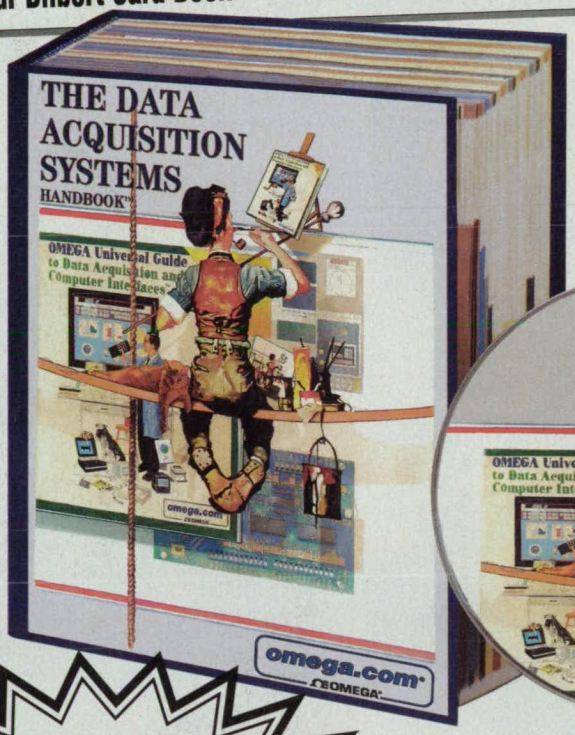

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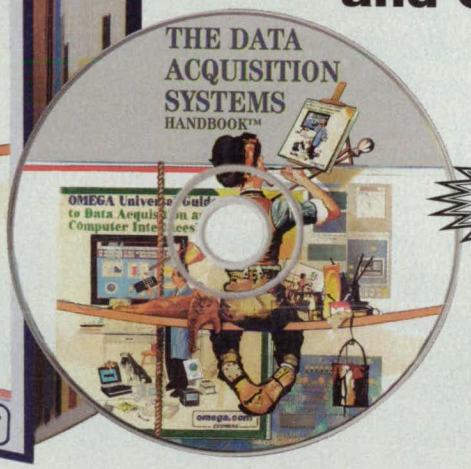

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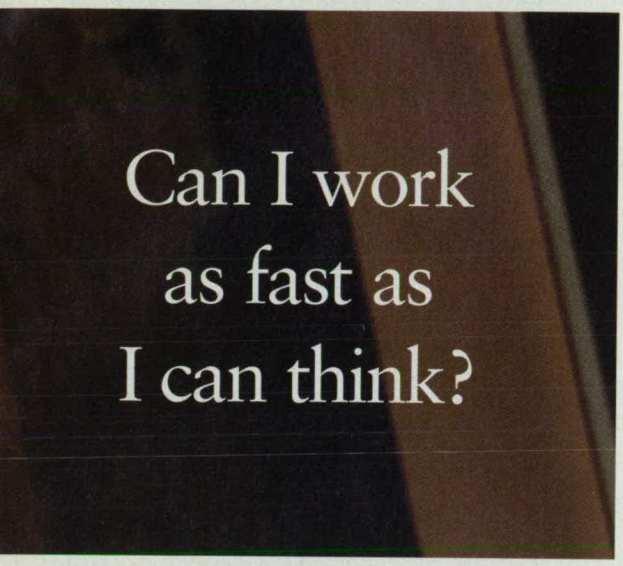

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TECH BRIEFS

January 1999 • Vol. 23 No. 1

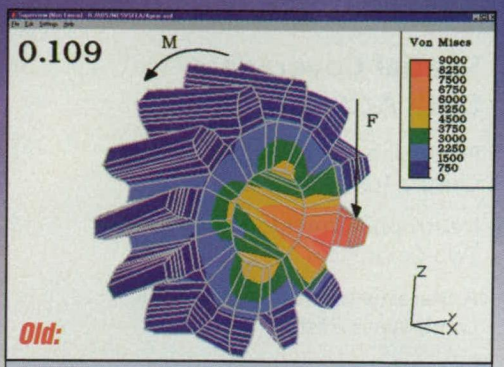
Features

Briefs

Departments

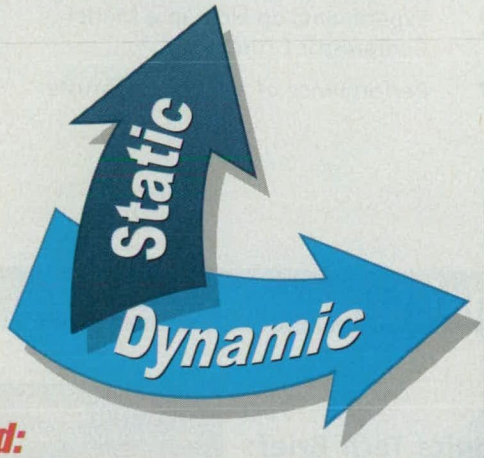
Tech East '98, held in Boston November 3-5, combined six major technology events and incorporated more than 100,000 square feet of exhibits. New inventions, seminars, and leading-edge products were viewed by nearly 8,000 attendees. The event also featured Small Business awards, NASA software awards, guest speakers, and a mock-up of the habitation module for the International Space Station. Highlights of the event begin on page 22.

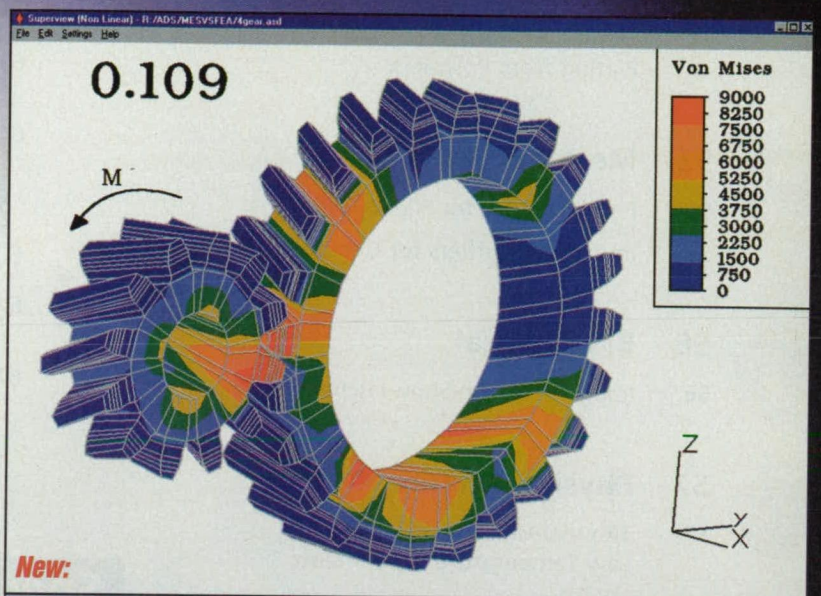
FEA Old vs. New



Old:

In Linear Static Stress Analysis, the forces must sum to zero. The effect of the second gear is simulated by an assumed force or pressure at a single instant in time.





New:

In Algor's Mechanical Event Simulation, the forces sum to Mass times Acceleration (F=MA). Impact forces are transmitted through actual contact between the teeth during gear acceleration.

Old:

In traditional linear static stress analysis, you begin by building an FEA model. Then you set up boundary conditions to anchor the model in three-dimensional space.

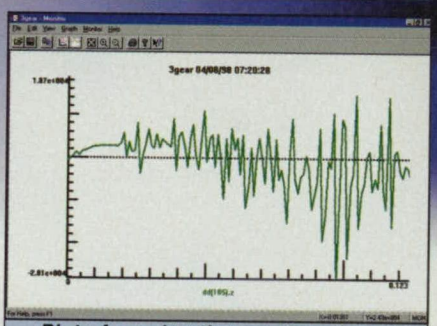
If the boundary conditions fail to stop the model from moving in all six primary directions (three degrees of freedom in translation and three in rotation), the static FEA process cannot work. After setting up the boundary conditions, you then apply the moment (M) or torque, which could be generated by an electric motor, and an assumed force (F) or pressure to simulate the reaction of the second gear. After analysis you will have a stress contour for one point in time.

Because the gear teeth are constantly clashing in a random way, the impact forces cannot be known with any precision.

New:

In Algor's Mechanical Event Simulation, you begin the same way by building an FEA model. However, this time you include the second gear.

You place boundary conditions at the pivots. The big gear is free to rotate when forced by the driving gear. Inertia of the entire gear system resists the force of the motor. When the analysis runs, you will know it's set up properly when you see the gears accelerating and stresses changing as you view the live on-screen "monitor program." At the end, you see the stresses on all the gear teeth at every point in time.



Plot of acceleration vs. time shows high-frequency impacts.

And, you can make an analysis replay to see the results in real time or slow motion. In addition, you can run a Fast Fourier Transform on the displacement data to highlight any dangers from resonance.

See an analysis replay of this Mechanical Event Simulation at www.algor.com, or order the latest video and CD-ROM information/demo pack by faxing the coupon, ordering from the web, e-mailing Algor or calling Algor.

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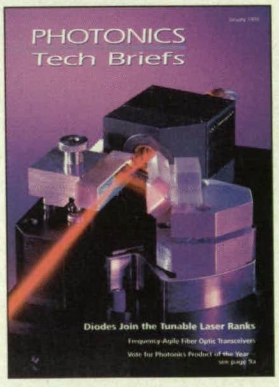

On the cover:

A new year of new technology begins with advances in Data Acquisition, one of this month's Special Coverage areas. The FW2000 Series Embedded Vehicle System (EVS) from FieldWorks, Eden Prairie, MN, is the first modular PC system for in-vehicle data communications and computing. The components — server, display, and backlit keyboard — all can be mounted separately. For more information on this and other innovations in data acquisition, see the special coverage beginning on page 60.

(Photo courtesy of FieldWorks)

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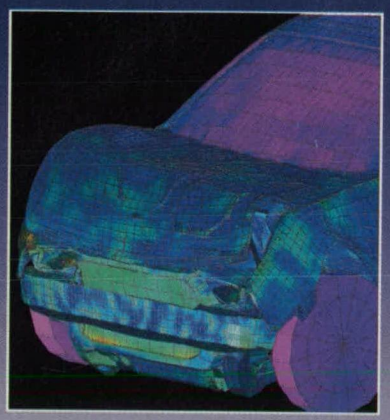

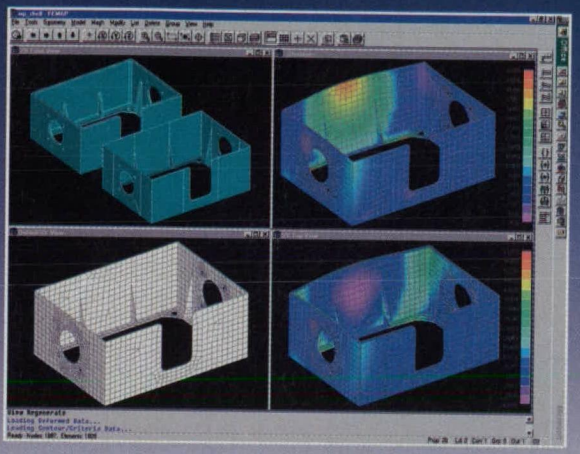

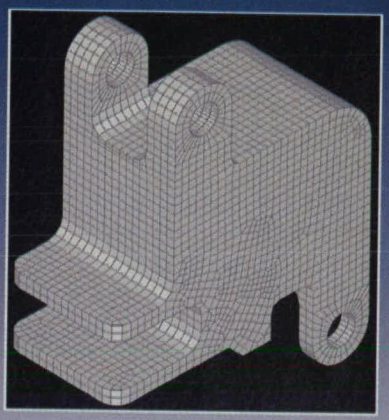

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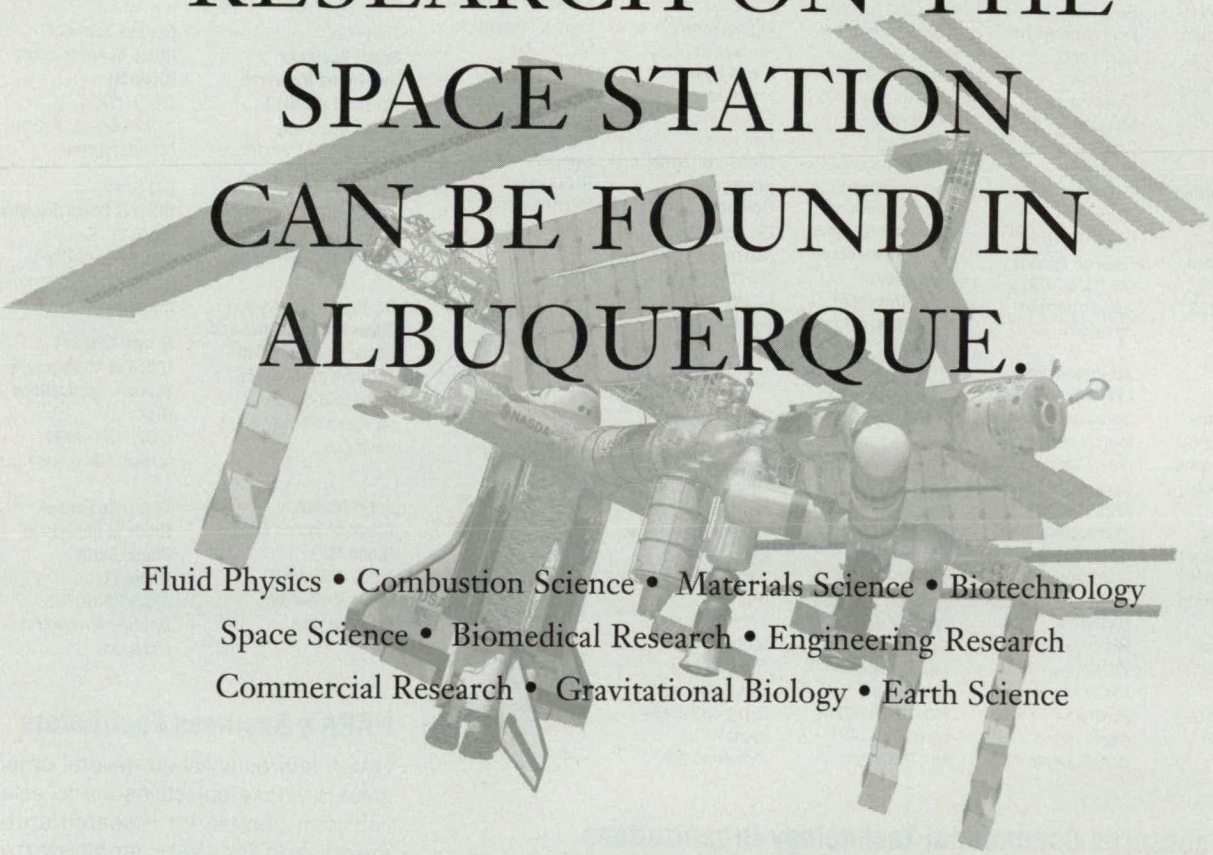

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NASA-Sponsored Commercial Technology Organizations

These organizations were established to provide rapid access to NASA and other federal R&D and foster collaboration between public and private sector organizations. They also can direct you to the appropriate point of contact within the Federal Laboratory Consortium. To reach the Regional Technology Transfer Center nearest you, call (800) 472-6785.

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NASA ON-LINE: Go to NASA's Commercial Technology Network (CTN) on the World Wide Web at **http://nctn.hq.nasa.gov** to search NASA technology resources, find commercialization opportunities, and learn about NASA's national network of programs, organizations, and services dedicated to technology transfer and commercialization.

NASA Program Offices

At NASA Headquarters there are seven major program offices that develop and oversee technology projects of potential interest to industry. The street address for these strategic business units is: NASA Headquarters, 300 E St. SW, Washington, DC 20546.

Carl Ray
Small Business Innovation Research Program (SBIR) & Small Business Technology Transfer Program (STTR)
(202) 358-4652
cray@mail.hq.nasa.gov

Dr. Robert Norwood
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(202) 358-2320
rnorwood@mail.hq.nasa.gov

John Mulcahy
Office of Space Flight (Code MP)
(202) 358-1401
jmulcahy@mail.hq.nasa.gov

Gerald Johnson
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(202) 358-4711
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Bill Smith
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Granville Paules
Office of Mission to Planet Earth (Code Y)
(202) 358-0706
gpaules@mtpe.hq.nasa.gov

NASA's Business Facilitators

NASA has established several organizations whose objectives are to establish joint sponsored research agreements and incubate small start-up companies with significant business promise.

Dr. Jill Fabricant
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Wayne P. Zeman
Lewis Incubator for Technology
Cleveland, OH
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Dan Morrison
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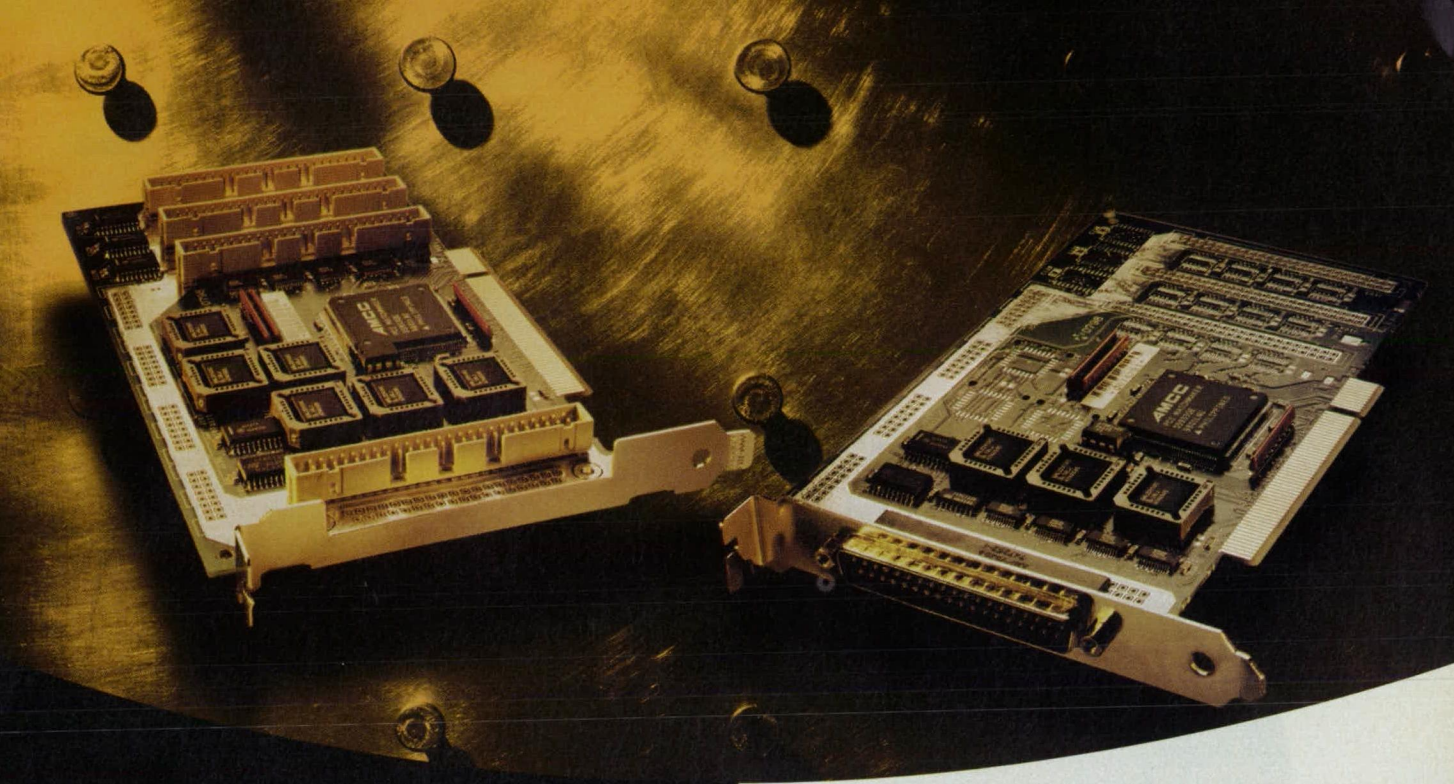
If you are interested in information, applications, and services relating to satellite and aerial data for Earth resources, contact: Dr. Stan Morain, **Earth Analysis Center,** (505) 277-3622.



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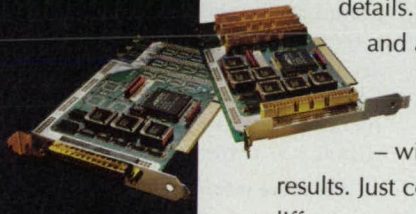

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For More Information Circle No. 573

UpFront

PRODUCT OF THE MONTH

Silicon Graphics, Mountain View, CA, has introduced the 320 and 540 system visual workstations, the company's first line based on the Windows NT operating system. The 320 system is a mini-tower workstation that can be configured with up to two Intel Pentium II 450 MHz processors, can support up to 1 GB of memory, and is offered with Ultra ATA or Ultra 2 SCSI disk drives. The 540 systems are full-tower, quad-capable Intel Pentium II Xeon workstations that can be configured with up to four Xeon 450 MHz processors. They can support up to 2 GB of memory and are offered with fast Ultra 2 SCSI disk drives. Both workstation lines feature 8-, 16-, and 32-bit color formats; integrated audio and video subsystems; integrated I/O; and three front-accessible bays: a pre-installed 5.25" CD drive, a standard third-height pre-installed floppy drive, and an additional 3.5" drive.

For More Information Circle No. 750

Data Acquisition Association Formed

Leaders in the field of PC-based data acquisition have formed the Open Data Acquisition Association. The organization is dedicated to the development, promotion, and maintenance of a universal, open standard allowing interoperability between multiple vendors of data acquisition hardware and software. System designers will be able to select the most appropriate products from multiple hardware and software vendors, and easily integrate them into a single system. The standard specification is a public document, and all data acquisition companies are encouraged to conform.

Founding member companies are: ComputerBoards (Middleboro, MA), Data Translation (Marlboro, MA), Hewlett-Packard (Palo Alto, CA), LABTECH Corp. (Andover, MA), Microsoft Corp. (Redmond, OR), OMEGA Engineering (Stamford, CT), and Strawberry Tree (Sunnyvale, CA). All companies involved in computer-based data acquisition are welcomed to join. For more information, contact John Coschigano of OMEGA Engineering at 203-359-7808; coschigano@omega.com

NASA Langley Joins Flight 800 Probe

The National Transportation Safety Board has asked NASA to look further into the question of whether external electromagnetic interference (EMI) could have triggered the destruction of TWA Flight 800 on July 17, 1996, just south of Long Island, NY. Safety board officials want specialists at NASA's Langley Research Center in Hampton, VA — as well as the Navy's Flight Test Center in Patuxent River, MD — to analyze how much energy emitters of radiated fields within range of Flight 800 could have induced into the flight's center tank or the wiring around it, either individually or in combination.

NASA Langley, which was asked to lead the analysis effort, is one of the world's premier facilities for testing and studying the effects of high-intensity radiated fields on electrical and electronic components in aerospace and other applications.

There's Still Time To Vote!

The deadline for casting your vote for 1998 *NASA Tech Briefs* Product of the Year has been extended to January 29. Visit our web site at www.nasatech.com and complete the Readers' Choice Awards ballot. Remember, only one vote per person.

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Personal Computer World

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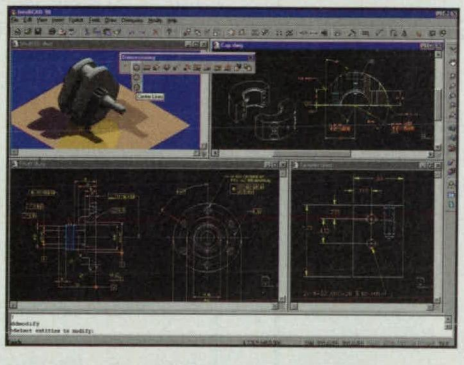
*PC Magazine**

When IntelliCAD® 98 by Visio was introduced in April, *Cadence* magazine wrote, "IntelliCAD represents a major victory for the CAD consumer by raising the bar of CAD software value." Since then, industry leaders have applauded the product's Autodesk AutoCAD compatibility, productivity features and affordability. Here's why. IntelliCAD 98 uses DWG as its native file format, just like AutoCAD. It can run in tandem with AutoCAD, and open AutoCAD files through version R14.01 without conversion or data loss. IntelliCAD 98 also provides support for AutoCAD commands, Autodesk AutoLISP programs, menus, dialogs and other legacy tools. Plus, it already runs over 100 AutoCAD applications from third-party developers, such as CIMLOGIC, Hitachi Software, and CYCO Software.



So don't confuse IntelliCAD 98 with a non-customizable, scaled-down version like Autodesk's AutoCAD LT. In fact, IntelliCAD 98 offers features not available in full-blown AutoCAD—like the ability to have multiple drawings open simultaneously, and cut and paste between them. Bottom line—IntelliCAD 98 costs only $349 ($149 when installed to a desktop currently running AutoCAD or AutoCAD LT**); it comes with a 60-day money-back guarantee; and 30 days of free technical support—you simply can't go wrong. Pick up a copy at your nearest retailer and find out what all the talk is about. For more information call 1-800-24-VISIO, reference A455. Or see it in action at **www.visio.com/tryit.**

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*April 28, 1998 issue.

For More Information Circle No. 541

Reader Forum

Reader Forum is devoted to the thoughts, concerns, questions, and comments of our readers. If you have a comment, a question regarding a specific technical problem, or an answer to a question that appeared in a recent issue, send your letter to the address below.

I'm looking for any and all information concerning pyrolytic graphite, including material specs, manufacturing processes, and vendors. I've been told that NASA began working with this material back in the 1950s, and has since moved to a different form of graphite. Any help would be appreciated.

Michael Mahaney
Mjmahaney@ionbeam.com

(***Editor's Note:*** *Michael, the first place to try for information on NASA's work with graphite is the National Technology Transfer Center [NTTC]. They can be reached at 1-800-678-6882.)*

I have developed a protective sleeve that protects a long-line catheter. The sleeve resembles a blood pressure cuff. The ends are made watertight by two adjustable silicone seals that wrap around the arm. To fasten the longitudinal joint, I have used a hook and loop fastener. This type of joint is not watertight. I am looking for a watertight hook and loop joint so that this sleeve can be used in a wet environment. Thank you.

David Williams
Iotano Services
Houston, TX
713-784-6982

A friend told me about an article he read in NASA Tech Briefs *about six months ago. The article was about a camera that produced Braille-like images. I produce a radio program heard on many radio reading services for the blind and disabled. I believe Travel Radio listeners would be interested in knowing about this camera. Would you be able to tell me where to find this information?*

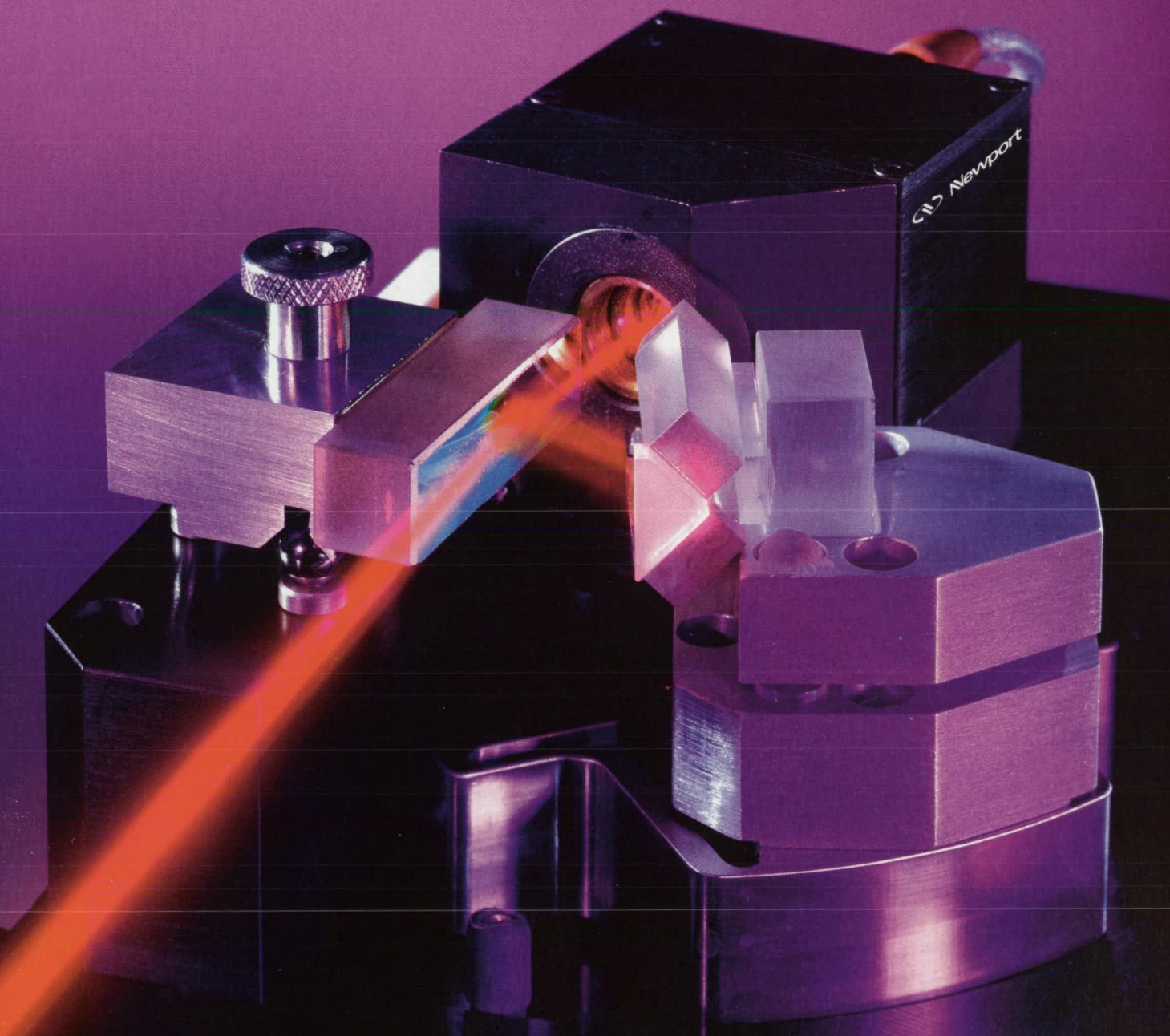
Patricia Lawrence, Executive Producer
Travel Radio
Mendocino, CA
707-964-7821

(***Editor's Note:*** *Patricia, the article appeared in the March 1998 issue of* NASA Tech Briefs. *"Sight-to-Touch Translator" on page 56 describes the work being done at NASA's Jet Propulsion Laboratory on a conceptual apparatus that would generate a tactile representation of visible objects in its vicinity. A copy of the brief, with instructions on how to obtain more information, is on its way to you.)*

Post your letters to **Reader Forum** on-line at: **www.nasatech.com** or send to: Editor, *NASA Tech Briefs*, 317 Madison Ave., New York, NY 10017; Fax: 212-986-7864. Please include your name, company (if applicable), address, and phone number or e-mail address.

January 1999

PHOTONICS Tech Briefs



Diodes Join the Tunable Laser Ranks

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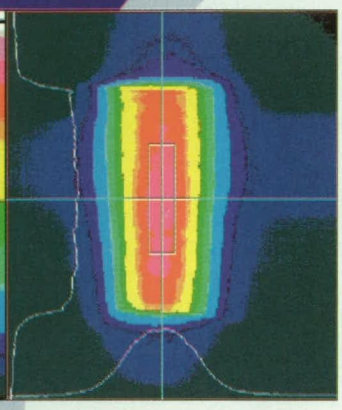
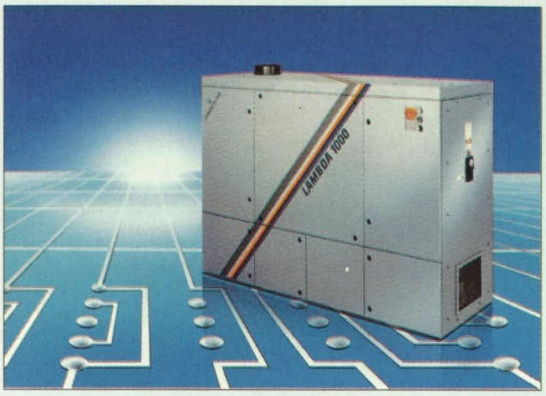


Beam Profile, L1-FBG



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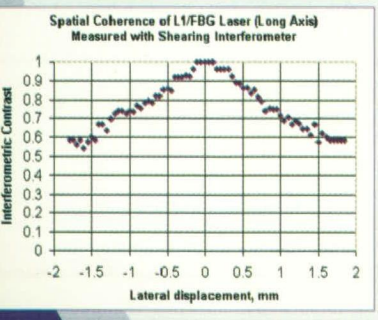

Spatial Coherence Measurement, L1-FBG

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Wait a Minute... Who's Kobayashi?

OptoSigma's Mitsuo Kobayashi is a dreamer. He didn't discover gravity or a new moon, but awoke early one morning with a revolutionary new concept in opto-mechanical positioning. After a few quick sketches, he rushed to work. It didn't take long for us to realize that his extended contact bearing stage was an astronomical leap forward. The rest is history.

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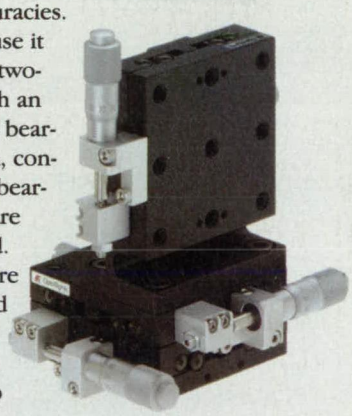

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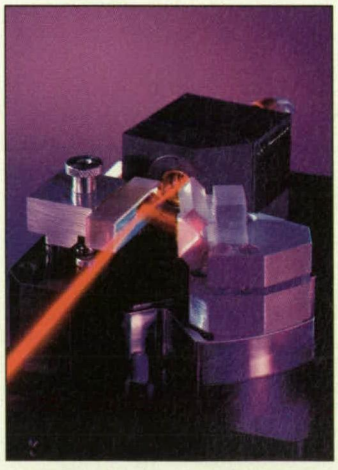

On the cover: Newport Corporation's 2010 series of tunable diode lasers opens up new areas of applied spectroscopy, from quantifying the sweetness of fruit to monitoring fetal brain oxygenation during delivery. *Photo courtesy Newport Corporation.*

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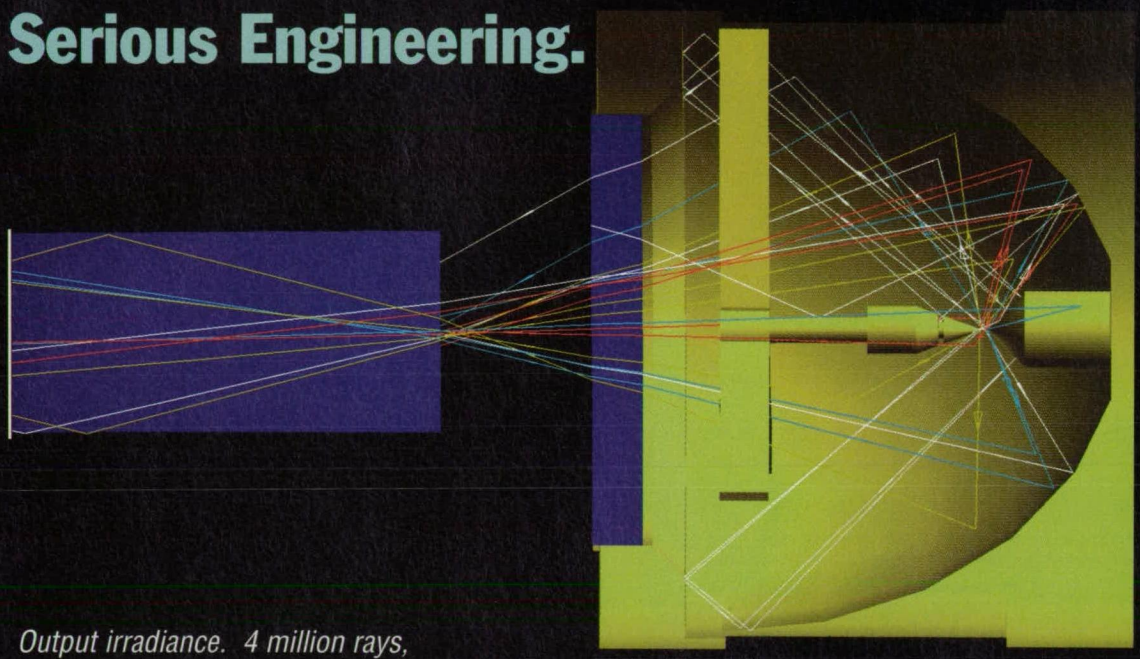

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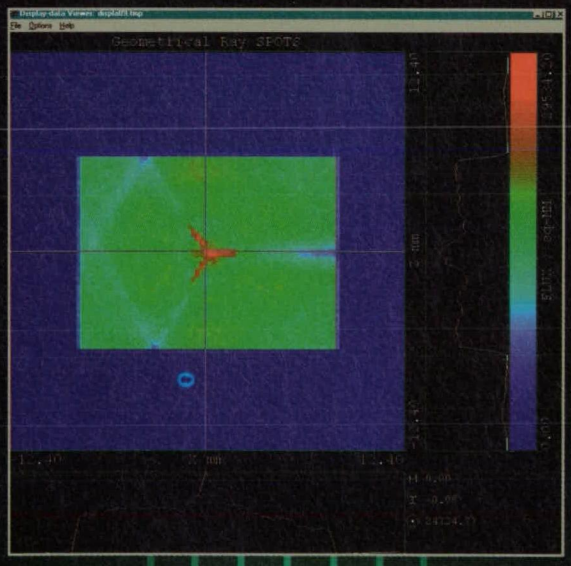

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DIODES STORM THE TUNABLE

Near-IR absorption spectroscopy using tunable lasers enables rapid nondestructive evaluation of natural produce such as onions, melons, and potatoes.

Tunable lasers first became commercially available around thirty years ago, revolutionizing the field of spectroscopy. Since that time, these lasers have enabled an ever-widening range of diverse applications, from laser-induced fluorescence of biopolymers to Doppler-free measurements of atomic hyperfine structure. Until very recently, however, the cost, size, and complexity of tunable laser systems have limited their use to the research laboratory, whereas lamp-based spectroscopy has long been appropriately packaged for field use. This is unfortunate, as laser-based spectroscopy is generally far superior, and can often provide an excellent answer to the ever-growing demand for sensitive, noninvasive, real-time diagnostics.

The situation is now changing due to the development of the tunable diode laser, a completely new type of tunable laser source. These rugged, compact lasers are typically only 1/20th the size of traditional tunable laser systems; they offer true turnkey simplicity for 1/10th the cost of their complex predecessors, yet deliver equivalent or better performance. Based on the simple semiconductor chips used in telecommunications and compact disk players, these lasers are now opening whole new areas of applied spectroscopy, from quantifying the sweetness of fruit to monitoring fetal brain oxygenation during delivery.

TUNABLE DIODE LASERS

Laser diodes are small, monolithic solid-state devices that efficiently convert electricity into laser light. Manufactured by standard semiconductor fabrication techniques, they offer low cost in high volume. In addition to their long lifetime, they require only a low-voltage power supply and no water-cooling. Laser diode chips are now available at most wavelengths between 630 nm and 2.4 microns, and most of these devices are capable of emitting laser radiation over several tens of nanometers. In principle, therefore, laser diodes are virtually ideal sources of tunable laser light in the red and near-infrared spectral regions.

As with any tunable laser medium (*e.g.*, dye, titanium sapphire), the wavelength of a laser diode must be actively controlled. Otherwise, the output will be unstable, consisting of a rapidly varying cluster of wavelengths (modes) centered on the wavelength of highest gain. With laser diodes, this control is best provided by utilizing an external cavity that incorporates wavelength-selective feedback. Tunable monolithic devices, such as DFB (distributed feedback) lasers, are available for telecommunications systems, but their scan range is generally far too narrow for most spectroscopic purposes.

Figure 1 schematically illustrates the main elements of an external-cavity diode laser, Newport's Model 2010 series tunable diode laser. The output wavelength is controlled by a diffraction grating. In this so-called Littman-Metcalf cavity, the wavelength is adjusted by rotating the tuning mirror, thereby effectively changing the feedback angle of the diffraction grating. Using this approach, the series 2010 lasers from Newport Corporation deliver a linewidth of 100 kHz and a maximum scan speed of 25 nm/sec, yet the entire laser head measures less than 175 cm × 100 cm × 75 cm. The power supply is similarly compact.

Two other aspects of this design merit special mention. First, the laser beam always exits the cavity at the same angle, no matter what the output wavelength. Among other benefits, this permits highly efficient fiber coupling. Just as important, the laser diode and collimating lens are assembled in a low-cost module. Kinematic "plug-and-play" mounting enables simple field interchange of these modules, allowing the wavelength range to be quickly changed without any cavity realignment.

TAKING TO THE FIELD

While these lasers are fast replacing traditional tunable lasers for many types of demanding laboratory experiments, it is in field applications that they are having their most revolutionary impact. These applications include those that formerly used lamp-based spectrometers, as well as new applications that were hitherto impossible.

LASER RANKS

Low-cost, rugged, compact sources of tunable laser light support the rapid growth of applied spectroscopy, from fetal monitoring to fruit sweetness quantification.

All these applications involve some type of absorption measurement, and a high-performance tunable laser offers several important advantages over a lamp-based spectrometer in this area. First, these lasers provide extremely high spectral brightness, over 30,000 times greater than a typical lamp spectrometer. Together with the low amplitude and frequency (wavelength) noise, this brightness allows weakly absorbing systems to be measured with unprecedented signal-to-noise ratio and short data-acquisition times. In addition, the laser's coherence allows a whole new type of absorption measurement, using a so-called "ring-down" cavity.

For applications that only require measurements on a single absorption feature, such as sugar in fruit (or blood), the laser is far superior to the use of two or three

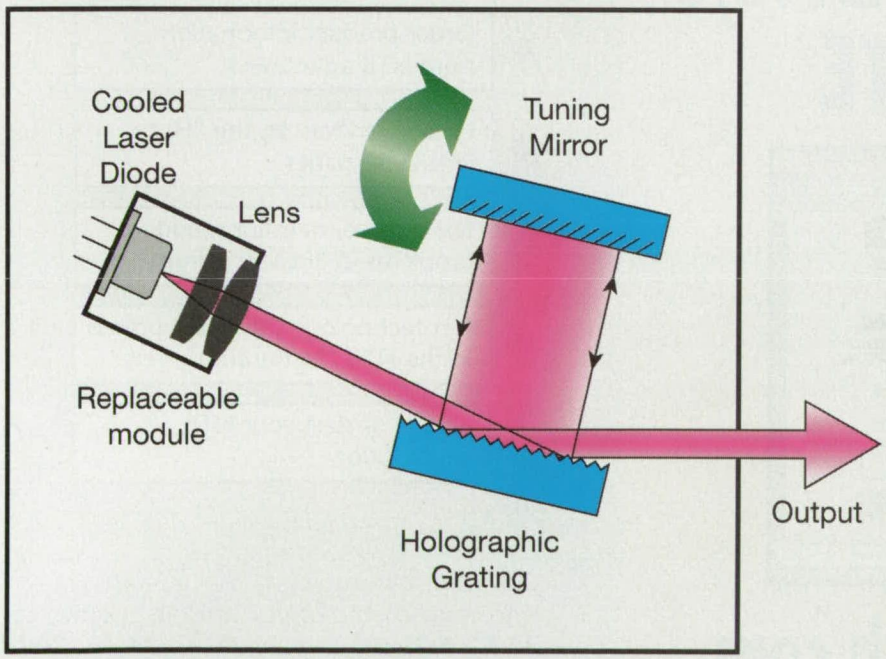


Figure 1. Commercial external-cavity diode lasers use a Littman-Metcalf cavity in which smooth tuning is provided by rotation of a mirror.

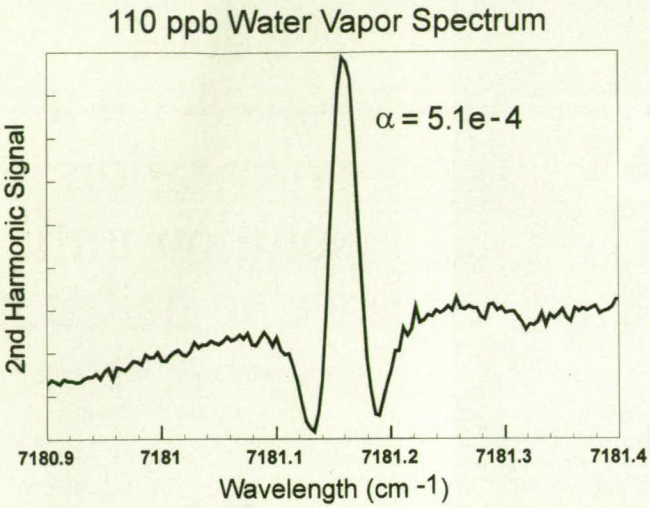


Figure 2. Diode laser spectrum of part of the 1.3-micron water absorption band using second-derivative detection and a multipass cell with 46.5-m optical path. The water-vapor concentration is only 110 ppb in this 100 Torr sample. *Data courtesy of Southwest Sciences.*

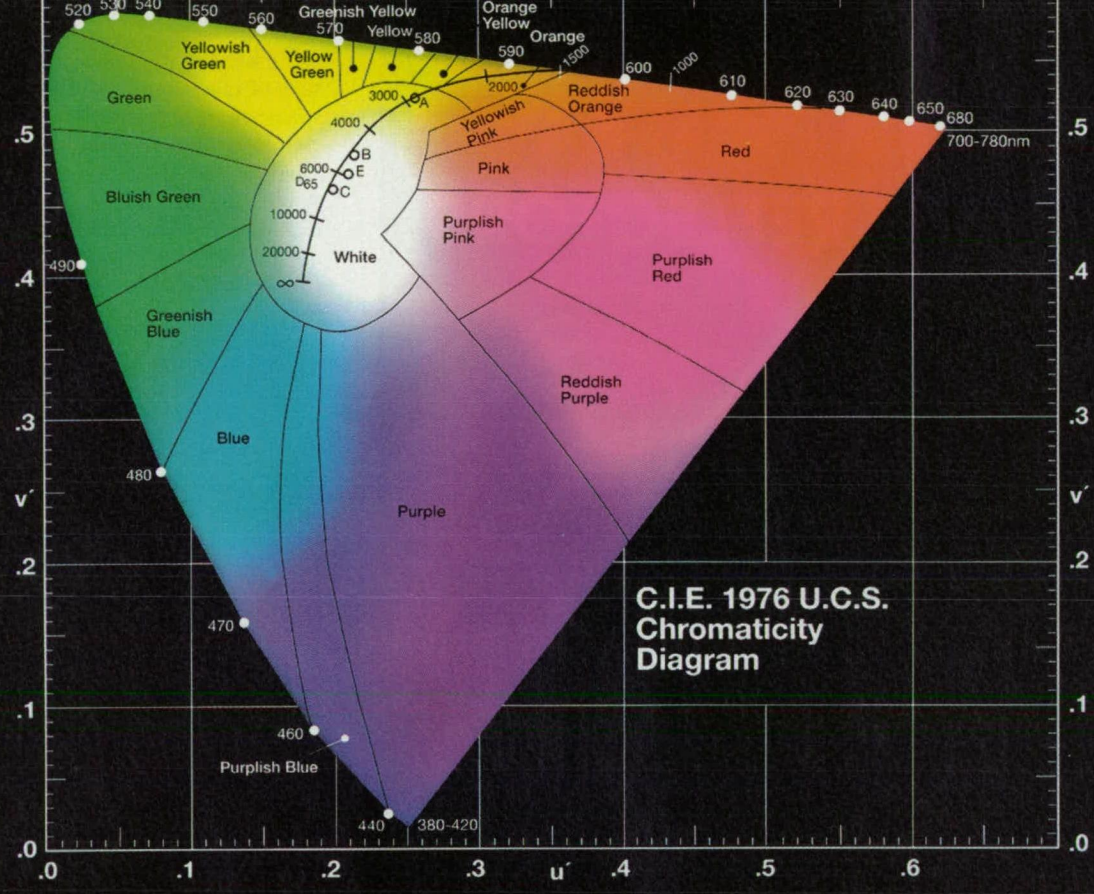
fixed filters. Specifically, its fast tuning allows these weak absorption signals to be distinguished from background variations, due to scatter and other phenomena, by wavelength-derivative measurement.

The range of applications that has been developed, or is under development, is already amazingly broad. A few examples include trace-gas analysis to monitor combustion emission, toxic gas leaks, and moisture in gases used for semiconductor fabrication (to the parts-per-billion level and beyond). In medicine, these lasers are being used to noninvasively monitor the oxygen level in a fetal brain during birth (by measuring the hemoglobin/oxyhemoglobin ratio in the 750-nm spectral region) and to characterize the state of arterial plaque. In agriculture and foodstuffs, measurement of hydrocarbon- and/or water-absorption features enables everything from quantifying dry matter in onions to determining water content in long-shelf-life baked goods.

To more fully appreciate the benefits of tunable diode lasers, it is useful to examine two of these applications, namely trace-gas analysis and agricultural produce, in a little more detail.

Two groups at the forefront of trace-gas spectroscopic analysis are Southwest Sciences Inc. (Santa Fe, NM) and Professor Kevin Lehman's team at Princeton University (Princeton, NJ). Mark Paige, a senior research scientist at Southwest Sciences, says that "of the gases that can be detected with diode lasers, trace-water-vapor detection holds the greatest industrial and government interest. With a multipass Herriott cell, we have measured sub-parts-per-billion water-vapor concentrations. This detection level is required for monitoring semiconductor process streams. We have also licensed diode laser technology to Ametek, Inc. for detecting hydrogen fluoride leaks in oil refineries and for monitoring ammonia in industrial stacks." He further notes that Southwest Sciences has measured absorbances as low as 10^{7} using diode lasers. "We're able to measure such small absorbances because diode lasers can be rapidly wavelength-modulated through current modulation. Second-derivative detection of the signal provides a background-free spectrum that also discriminates against light-scattering events." (See Figure 2.)

(Continued on page 8a)



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Laser Science, Inc.
A Subsidiary of Thermo Vision

provider of low cost laser light from UV through IR

8E Forge Parkway, Franklin, MA 02038 508-553-2353 800-447-1020
fax: 508-553-2355 www.laserscience.com

For More Information Circle No. 489

Rather than use a long optical path or a multipass cell, Lehman's group is using a relatively new technique to measure ultralow concentrations: ring-down spectroscopy. Here the laser beam "bounces" between two high-reflectance mirrors that define a resonant cavity. When the laser is abruptly switched off using a modulator, the light intensity in the cavity has a characteristic decay, or ring-down, time. Even a small absorption within the cavity can measurably shorten this time. Here the laser's narrow linewidth is critical in maximizing signal-to-noise. With this method, Lehman has now measured water vapor in nitrogen below the parts-per-billion level, and is collaborating to commercialize this technique with Meeco Inc., Warrington, PA, a leader in moisture sensing.

Agricultural Innovations Inc., Athens, GA, is a company that specializes in the use of near-infrared spectroscopy for nondestructive, noninvasive characterization of agricultural products. Gerald Dull, the president, notes, "The selling price of bulk produce is determined by several established quantitative measurements. With melons and other fruit, it's sugar content, with onions it's percent dry matter, and with potatoes for the chip industry it's usually both these parameters." Until recently, Agricultural Innovations' product line was built around conventional spectrometers and halogen tungsten lamps, but they are now developing diode-laser-based alternatives. Dull explains, "We are dealing with high-optical-density, high-moisture products and a large dynamic signal range. It may seem amazing, but we have passed measurable light from a conventional spectrometer through a full-size, unskinned honeydew melon, but not with acceptable signal-to-noise. With a diode laser, however, even a large melon can be characterized with no damage." These prototype instruments use 2f detection of the 910-nm carbohydrate band and the water peak at 958 nm.

Thirty years ago, the advent of continuously tunable laser light began a revolution in research spectroscopy. Now rugged, compact, economical tunable diode lasers have begun a similar revolution in applied spectroscopy, and are already performing sensitive diagnostics and measurement in many fields.

For more information, contact the author of this article, Michael Lang, Product Manager, Newport Corporation (formerly Environmental Optical Sensors Inc.), 6395 Gunpark Drive, Boulder, CO 80301; mlang @eosi.com; www.eosi.com.

Cast Your Vote for

PHOTONICS Tech Briefs

Second Annual Product of the Year Award

Each issue of *Photonics Tech Briefs* in 1998 carried a Product of the Month—a photonics product the editors felt was of special interest and value to readers who work with lasers, optics, fiber optics, video and imaging equipment. This month *Photonics Tech Briefs* readers are invited to vote for the one product you deem the standout among those chosen as Products of the Month. The product garnering the most reader votes will be named Photonics Tech Briefs Product of the Year.

Please read the descriptions below of the Products of the Month, and choose the ONE you feel should receive the Product of the Year award. On the ballot below please indicate clearly your choice in the appropriate box, and fax or mail the completed ballot to reach the editors by February 15, 1999. The Product of the Year will be announced in a subsequent issue.

Digital Laser Marking System Kit

Synrad, Mukilteo, WA, introduces what it calls the first laser marking system kit based on all-digital technology. The company says that anyone can purchase the partially assembled, self-contained kit of components, perform some minor integration, and have a system operating on a marking production line in just a few hours. At the heart of the system is the Synrad DH Series sealed RF-excited carbon dioxide laser marking head, based on digital and fiber optic technology and capable of 125 W output. Synrad says that its high noise immunity makes possible accurate and crisp marking on a variety of materials. Designed for industrial use, the laser can be expected to perform at specification for 35,000 continuous hours, the company says.

Low-Noise High-Speed CCD Camera

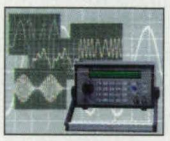
The AdaptIII™ CCD camera from PixelVision, Beaverton, OR, was designed for high-performance imaging at rates of up to 10,000 frames per second (fps). Featuring a back-illuminated CCD, it generates high frame rates through the use of multiple outputs and proprietary amplifier designs. Noise performance is as low as 3 electrons rms at 250 fps, the company says, and fewer than 12 electrons rms at 1250 fps. PixelVision uses 40 output amplifiers that are digitized, multiplexed, and sent over a serial fiber optic transmission link to the company's LynxPCI™ interface boards. AdaptIII is modular in design, and its electronics are housed in a rugged, hermetically sealed package.

Optical Linear Encoder

BEI Sensors & Systems Co.'s Encoder Systems Division, Sylmar, CA, introduces its LIE5 Series optical linear encoders, the first product to be developed under a new business alliance with Carl Zeiss Group. Called the most efficient microelectronic technology to result from an extensive research and development effort by the two companies, the LIE5 encoder is a reflective-read device that works in conjunction with a steel measuring scale. BEI says the head employs flip-chip-on-glass optics, which account for its small size as well as its ability to include built-in interpolation circuitry with resolutions as fine as 0.1 µm and output frequency up to 36 MHz. The head's dual scanning arrays allow for continued reading under contamination conditions that the company says would prove fatal to other linear encoders.

Goniometric Radiometer for Laser Diodes

Photon Inc., Santa Clara, CA, says its Model LD 8800 goniometric radiometer is specifically designed for measuring the radiation pattern emitted from a highly divergent source such as a laser diode or an LED. The company says the instrument, which precisely measures angular divergence and intensity distribution, is based on a proprietary patent-pending rapid scanning pinhole technique invented by Photon. This, the company asserts, makes possible measurements in a few seconds that previously could take hours. Single goniometric scans are done at 10 Hz and a full 3D characterization is completed in about one minute. Sampling resolution in the angular direction is 0.05° and in the azimuthal direction less than a degree.



20-MHz Benchtop Signal Generator

Berkeley Nucleonics Corp., San Rafael, CA, says the Model 625A SmartARB function, pulse, and arbitrary waveform generator was designed to provide more operating modes, more functions, and more measurement modes than any other unit in its price class. The arb clock is fully synthesized, unlike a clock generated by a DDS phase accumulator, which can result in phase jitter and missed points when the arbitrary waveform frequency is changed. The 625A's modes include standard sine, square, ramp, triangle, and random waveforms, but also AM, FM, PM, SSB, FSK, BPSK signal modulation, DTMF generate, DTMF detect, voltage and power measurement, and data and word generation.

Long Phase Mask

The LPM Series long phase mask from Lasiris Inc., St-Laurent, Quebec, Canada, combines the high accuracy achievable by two interfering laser beams, the company says, with the most reliable and repeatable phase-mask fabrication process ever designed. Within its 100-mm grating length, it eliminates the stitching error or phase error associated with E-beam mask technology, which Lasiris says makes it perfect for fabricating dispersion compensation fiber gratings. Long phase masks are available in constant period and linear chirp.

1998 *Photonics Tech Briefs* PRODUCT OF THE YEAR BALLOT

Indicate your choice by clearly marking the appropriate box. Fax or mail your completed ballot to Robert Clark, Senior Editor, *Photonics Tech Briefs*, 317 Madison Avenue, Suite 1900, New York, NY 10017, before February 15, 1999; Fax: (212) 986-7864.

- ❑ **February:** Synrad Digital Laser Marking System Kit
- ❑ **April:** PixelVision AdaptIII CCD Camera
- ❑ **June:** BEI Sensors & Systems LIE5 Series Optical Linear Encoder
- ❑ **August:** Photon Inc. Model LD 8800 Goniometric Radiometer
- ❑ **October:** Berkeley Nucleonics Model 625A SmartARB Arbitrary Waveform Generator
- ❑ **December:** Lasiris Long Phase Mask

Name: _____

Company: _____

Address: _____

City, State, Zip: _____

Phone: _____

Fax: _____

E-mail: _____

Dielectric Coating Grading Method

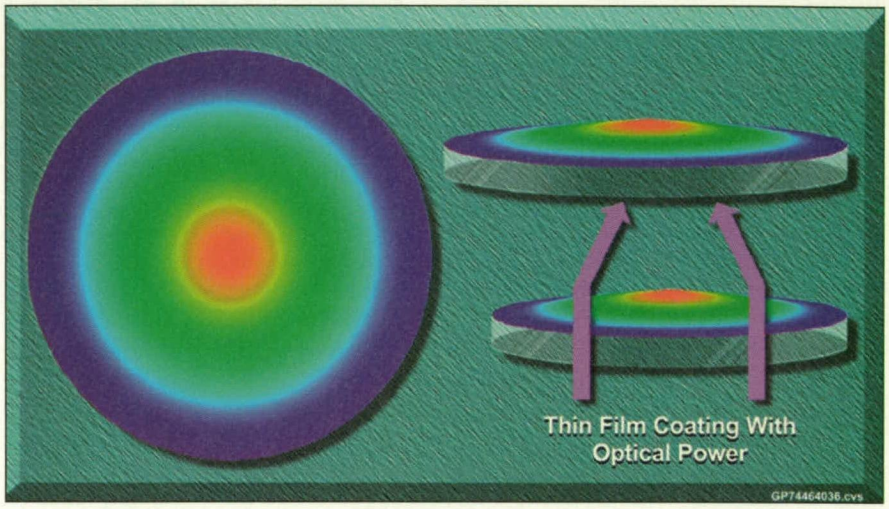
A post-processing method can also be applied to high-value coated optics.

The Boeing Company, St. Louis, Missouri

In a filing before the U.S. Patent and Trademark Office, the Boeing Company has disclosed a post-processing method for dielectric combiner elements that may reduce the cost of grading dual combiner sets by 90 percent compared to currently produced dielectric types.

One problem encountered with nongraded dual combiner sets is an optical defect that appears which appears when viewing the overlap region between the two elements: a dark band that can be mistaken for an artificial horizon becomes visible. In addition, the displayed data in the overlap region appears brighter, producing objectionable nonuniformity in both the transmitted and received images.

In the past these problems have been solved by grading the overlap zones on each of the elements during coating of the substrates. But these methods are relatively expensive and require considerable skill, experience, and capital investment.



Boeing's method is a post-processing etching performed on nongraded coated combiner elements. The coating has been applied to test articles of various substrates and has produced uniformly high-quality results, including predictable grading results and integrity of the nonetched coating.

The grading coating is best applied to dielectric combiner elements. where it can be used to reduce cost significantly. The process can be applied equally well to

high-value coated optics, where a grading is required. It may be useful on large coated optics or structures with an optical component such as canopies, windows, and mirrors.

The Boeing Company *is currently developing business relationships with companies interested in applying Boeing technologies to their products. If actively interested, please contact Dennis Donahue, Marketing Manager, Licensing; MC 306-1285, PO Box 516, St. Louis, MO 63166; (314) 234-7093; fax (314) 232-4313; http://www.boeing.com/assocproducts/mdip.*

Optical Cavity-Ring-Down Measurement of Soot Concentration

Sensitivity and temporal resolution exceed those of any other technique now in use.

Lewis Research Center, Cleveland, Ohio

An optical technique for measuring the concentration of soot in air is based on the cavity-ring-down (CRD) principle, which is so named because it involves observation of the decay ("ring-down") of a signal echoing in a cavity. By use of (1) the observed rate of decay and (2) a known relationship between the rate of decay and the quantity of something that contributes to the decay, one calculates this quantity. In this case, the ring-down cavity is an optical one, the absorption and scattering of light by soot contributes to the decay of an optical signal, and the concentration of soot is the quantity to be determined from the measured rate of decay.

The ring-down cavity is bounded by two confocal mirrors with a radius of curvature equal to or greater than the distance between them. Pulsed laser light is prepared for coupling into the cavity by spatial filtering followed by down-collimation to match the TEM_{00} mode of the cavity. A photomultiplier tube or an amplified positive/intrinsic/negative (PIN) silicon photodiode detects light coming out of the cavity. The output of the photodetector is sent to a transient-signal digitizer. The digitized signal is processed to determine its ring-down time (τ) or, equivalently, its rate of decay (k).

The ring-down time is given by

$$\tau = \frac{1}{k} = \frac{d}{c\left[1 - R + \left(k_e f_v L/\lambda\right)\right]}$$

where d is the distance between mirrors, c is the speed of light, R is the reflectivity of the mirrors, k_e is a constant of proportionality for the amount of absorption of light in soot, f_v is the soot concentration (expressed as a volume fraction), L is the distance over which soot is distributed, and λ is the wavelength of the laser light. One potential source of error is uncertainty in the value of k_e; this value can be calculated from the index of refraction of soot, which is not known to better than about 10 percent. The equation can be solved for the concentration of soot:

$$f_v = \left(\lambda/k_e L\right)\left[\left(d/c\tau\right) + R - 1\right]$$

The sensitivity of this CRD technique exceeds that of any other soot-measurement technique now in use; it enables measurement of soot concentrations in the range from 1 to 100 parts per billion. The temporal resolution of this technique is also greater than that of any other soot-measurement technique. CRD has a good spatial resolution in directions orthogonal to the cavity axis but suffers from a lack thereof along this axis. However, CRD could be used along with laser-induced incandescence (LII), which gives spatially-resolved relative concentrations. Because the CRD signal for a given path is proportional to the path-integrated LII signal, CRD measurements could be used to calibrate LII measurements. CRD, either alone or in combination with LII, could be used to measure concentrations of particulate matter in the atmosphere at large, in industrial aerosols and in the exhausts of gasoline engines, diesel engines, power plants, and incinerators.

This work was done by Randall L. Vander Wal of NYMA, Inc., for **Lewis Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

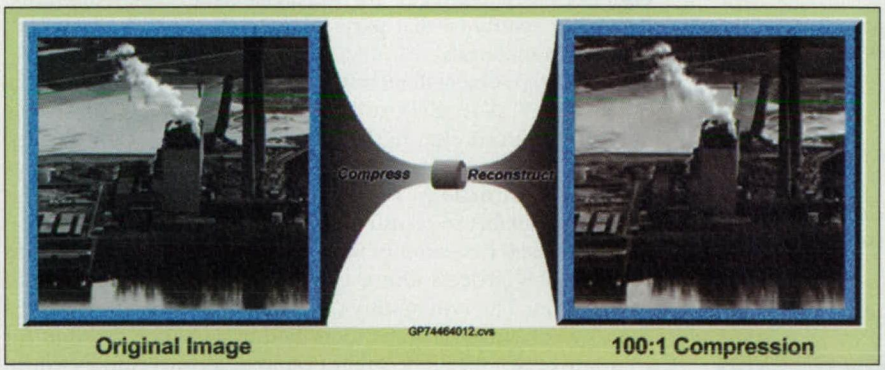
Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7–3, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16541.

Wavelet-Based Image Compression Software

The approach pushes the upper boundary of useful compression ratios as high as 200:1.

The Boeing Company, St. Louis, Missouri

The Boeing Company has developed wavelet-based image compression software that offers state-of-the-art compression of still imagery, providing superior image quality at compression ratios ranging from several to one up to 200:1. The algorithm compares favorably with the Joint Photographic Experts Group (JPEG) standard in both image quality and algorithm speed at all compression ratios, and is dramatically better than JPEG for compression ratios over 30:1.



With the proliferation of digital imagery in a variety of applications, image compression is becoming a critical enabling technology. An efficient compression approach allows orders of magnitude reductions for image storage, transmission bandwidth, and/or transmission time. Boeing's wavelet-based approach improves image quality and pushes the upper bound of useful compression ratios as high as 200:1.

The algorithm is currently implemented in ANSI standard C source code, and has been hosted on personal computers, UNIX workstations, and DSPs. It has been successfully demonstrated for several defense applications and is readily transitionable for commercial applications. Current development efforts are focused on continued improvement in image quality, and extensions for color imagery and video imagery (using motion prediction). The algorithm is computationally efficient and highly parallel, making it well suited for real-time VLSI implementation.

Potential applications are seen in law enforcement, communication systems, graphics/imaging workstations, medical imaging, videoconferencing, intelligent vehicle highway systems, multimedia, remote sensing, the information superhighway, document imaging, and remotely piloted vehicles.

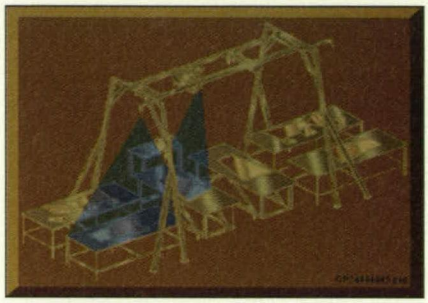
The Boeing Company *is currently developing business relationships with companies interested in applying Boeing technologies to their products. If actively interested, please contact Dennis Donahue, Marketing Manager, Licensing; MC 306 1285, PO Box 516, St. Louis, MO 63166; (314)-234-7093; fax (314) 232-4313; http://www.boeing.com/assocproducts/mdip.*

Video-Based Foreign Object Detection

The technique can be applied to any assembly process where inclusion of foreign material can cause harm.

The Boeing Company, St. Louis, Missouri

The Boeing Company has developed an overhead camera system that can automatically spot small pieces of debris on a work surface that might otherwise go unnoticed. The system automatically analyzes inputs from one or more video cameras to detect undesirable colors representing materials that, if left in place, would degrade part quality. The system uses commercial off-the-shelf hardware and software for low-cost implementation and is currently in use in the Boeing F/A-18 wing



production line (see figure). The patent-pending technology, known as foreign-object video detection and alert system and method, is available for license.

Specifically, the system requires that an area within the camera's field of view be designated as the area of interest. Then the system is exposed to foreign-object samples, work pieces, and tooling to build a library of good and bad colors. Various logical comparisons can be made, such as rejecting all colors except for that of the work piece. This greatly reduces the requirement for preexposure to foreign objects.

The video-based foreign-object detection system provides a low-cost means to improve first-time quality, thereby reducing the need for inspection and rework. Parts rejections are decreased, as are resulting delivery delays. Documentation is enhanced when images are retrieved from system memory, providing assurance that parts were produced without included foreign materials.

The foreign-object detection system is currently in use in production of F/A-18 C/D and E/F composite wing skins. It is being introduced elsewhere in the Boeing production facility. Documentation includes an operator's manual and system programming instructions. Technical staff which implemented the system is available to transfer system knowledge to licensees.

Video-based detection of foreign materials can be applied to any assembly process where inclusion of foreign material can cause harm. The system also can be applied to scene monitoring when anomalies can be identified by a change in color. An example of this would be a flight ramp or airport runway where foreign objects would be of a different color than the background tarmac.

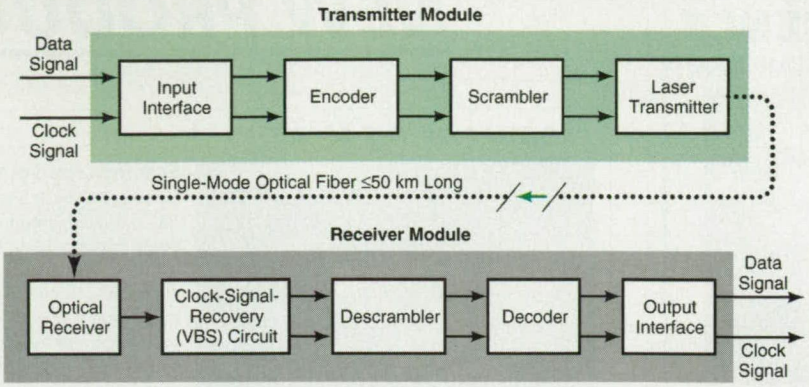
The Boeing Company *is currently developing business relationships with companies interested in applying Boeing technologies to their products. If actively interested, please contact Dennis Donahue, Marketing Manager, Licensing; MC 306-1285, PO Box 516, St. Louis, MO 63166; (314) 234-7093; fax (314) 232-4313; http://www.boeing.com/assocproducts/mdip.*

Frequency-Agile Fiber-Optic Transceivers

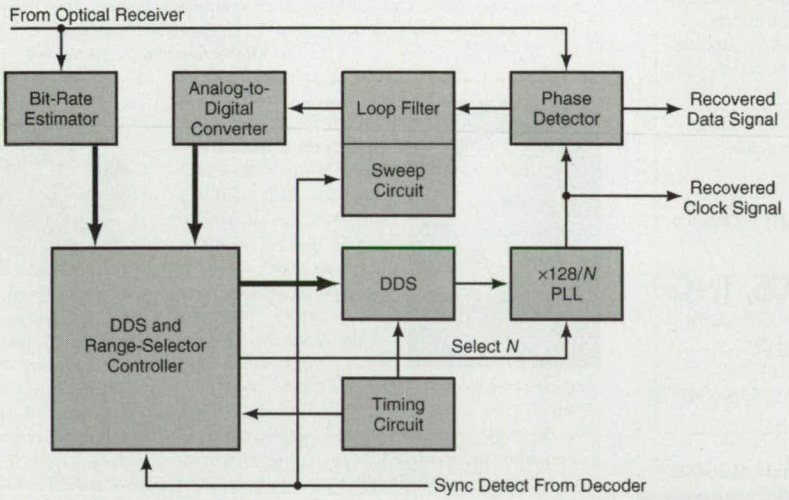
These transceivers handle data signals over a 30:1 frequency range.

Goddard Space Flight Center, Greenbelt, Maryland

Fiber-optic transceivers (FOTs) that can handle digital signals at any bit rate from 10 to 300 MHz have been developed. These variable-rate FOTs offer considerable advantages over fixed-rate FOTs that have been used until now. A fixed-rate FOT contains clock- and data-signal-recovery circuits tuned to the data rate. In a system in which data streams are transmitted at different rates, the data rates must be specified in advance, and a separate fixed-rate FOT must be designed, constructed, and installed for each rate. Thus the cost of acquiring, maintaining, and operating fixed-rate FOTs for a multiple-rate system can be high, and under some circumstances, advance



BLOCK DIAGRAM OF A VARIABLE-BIT-RATE OPTICAL DATA LINK



BLOCK DIAGRAM OF CLOCK-SIGNAL-RECOVERY (VBS) CIRCUIT

The **Clock-Signal-Recovery Circuit Is the Critical Unit** that implements the VBS process and thereby enables the fiber-optic transceiver to handle data at any rate over a wide range.

notice of data rates could compromise security. Obviously, costs can be reduced and security enhanced by use of variable-rate FOTs capable of operating over the full range of data rates.

Each transceiver includes a transmitter and a receiver module (see figure). The primary function of the transmitter module is performed in an encoder, which inserts one overhead bit for every eight data bits in a non-return-to-zero (NRZ) serial data stream. The overhead bits are used to prevent lockup in a scrambler, and they remove all constraints on the input data pattern. The rate of the transmitted serial data stream is thus 9/8× the input data rate.

In the receiver module, an optical receiver converts the incoming light signal to a bit-serial electrical signal. This electrical signal is fed to a clock-signal-recovery circuit, which implements a method, called "variable bit synchronization" (VBS), for recovering a clock signal characterized by a rate that could vary over a wide range. In VBS, the synchronous clock signal is reconstructed from the composite (clock + data) bit-serial electrical signal, then the data signal is regenerated with reclocking. The VBS process is what makes it possible to transmit NRZ data and clock signals over a communication channel and to recover these signals within a wide frequency range.

The lower part of the figure illustrates the clock-signal-recovery circuit and the VBS process in more detail. A bit-rate estimator provides an estimate of the incoming data rate. The estimate is used by a direct digital synthesizer (DDS) to acquire the clock frequency and achieve synchronization as follows: The output of the DDS is processed through a phase-lock loop that multiplies frequency by a factor of $128/N$ (where N is an integer). A controller sets up the DDS and PLL to generate a signal with a frequency within 3 percent of the actual clock frequency. The DDS is then swept into exact frequency and phase lock by a vernier sweep circuit. Typically, the clock-signal-acquisition process takes about 2 seconds.

The clock and data outputs of the clock-signal-recovery circuit are fed to a descrambler. The output of the descrambler is fed to a decoder, which strips off and frame-locks to the overhead bits and reconstructs the original NRZ data stream. The decoder also performs an 8/9 frequency multiplication on the reconstructed clock signal to recover the clock signal of the original data stream. The overhead bits and the frame-synchronization process that involves the overhead bits provide a benefit of continuous in-service error detection.

One particularly attractive feature of the variable-rate FOT is its ability to function without intervention by a technician once it has been installed. In operation, the receiver reconstructs the original clock and data signals at their original rates, with a bit-error rate of 10^{-12} or less.

This work was done by Chi Le of **Goddard Space Flight Center**, *Paul Casper of Broadband Communications Products, and Jim Shaughnessy of Computer Sciences Corp. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Systems category. GSC-13782*

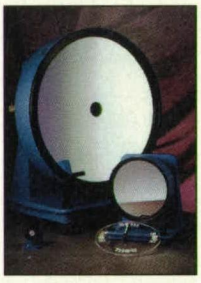
NEW PRODUCTS

PRODUCT OF THE MONTH

Spectroscopy System with Autocalibration

Lambda Physik, Ft. Lauderdale, FL, says its ScanMate™ OG is a complete tunable system for spectroscopists doing critical work in the UV, visible, and near-IR. It is continuously tunable from 320-1036 nm (line width <0.03 cm^{-1}). Its pulsed dye laser, which produces 95 mJ at 590 nm, comes equipped with an integrated autocalibration system that includes 8-channel data acquisition and comprehensive spectroscopic software called LP SCAN OG. The latter records and calibrates the spectra, allowing for semi- and fully automatic calibration related to atomic line positions measured by an integrated hollow cathode lamp. It also calibrates the laser drive, tuning the laser to the selected wavelength with an accuracy of better than 5 pm, Lambda Physik says.

For More Information Circle No. 760



New Mirror Materials Capability

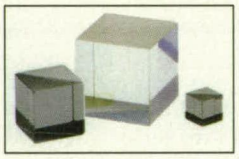
Space Optics Research Labs (SORL), Chelmsford, MA, has expanded its selection of substrate materials for its wide selection of off-axis parabolic mirrors. New materials include silicon, pyrex, fused silica, the zero-expansion ceramic Zerodur™, electroless nickel-coated aluminum, copper, and Glidcop™. SORL says the new materials permit applications to extend into high-powered lasers, cryogenics, laser fusion, and others. All elements are custom-ground and polished.

For More Information Circle No. 763

Ultrahigh-Temperature Coatings

Deposition Sciences Inc., Santa Rosa, CA, is offering custom cold mirror and color filter coatings for extremely high-temperature applications such as those using high-intensity discharge lamps. The company uses its patented MicroDyn™ microwave-assisted sputtering process that, according to Deposition Sciences, enables the uniform coating of flat, highly curved, and cylindrical parts, and yields thin films with exceptional mechanical durability and heat-handling capacity in excess of 1300 °C. The company says the coatings are also useful for the glass and ceramic reflectors used with high-intensity sources.

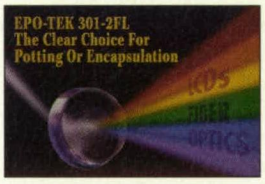
For More Information Circle No. 764



Low-Polarizing Cube Beamsplitters

The new line of low-polarizing cube beamsplitters from Opto-Sigma, Santa Ana, CA, is made from a hybrid metallic and dielectric coating, which, the company says, produces an even split in intensity with minimal absorption and polarization. They are offered in popular broadband wavelengths, including the visible (400-700 nm) and near infrared (600-900 nm), as well as in ultrabroadband wavelengths (400-1100 nm and 800-1600 nm). The beamsplitters are made from optical-grade BK-7. Four standard sizes of 5, 10, 15, and 20 mm are available from stock for each wavelength range.

For More Information Circle No. 765



Clear Epoxy for Potting

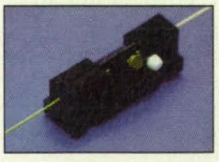
Epoxy Technology, Billerica, MA, offers EPO-TEK 301-2FL, a two-component low-stress optical epoxy designed for fiber optic and optical potting or encapsulation applications in which stress-sensitive properties are paramount to the component being bonded, coated, or potted. The company says that the new epoxy maintains clarity before and after curing, unlike many similar epoxies, and that it exhibited no loss of adhesion or decoupling when subjected to 95-percent relative humidity and 30 to 60 °C for five days per MIL-STD 810E.

For More Information Circle No. 770

Nd:YAG Laser System

New Wave Research, Sunnyvale, CA, calls its Tempest™ a compact, high-performance Nd:YAG laser system featuring harmonic wavelengths of 532 nm, 355 nm, and 266 nm in addition to the standard 1064 nm. The flashlamp-pumped system is designed for laser-induced breakdown studies, Raman spectroscopy, laser ablation, and similar applications. Tempest provides energy output as high as 200 mJ per pulse at 1064 nm and offers repetition rates of 10 Hz, 20 Hz, and 30 Hz. The system, which measures 13.0 × 7.0 × 3.5 in., comes complete with a power supply and control panel with all laser controls, including an optional optical attenuator. New Wave says the unit is easy to set up and operate.

For More Information Circle No. 768

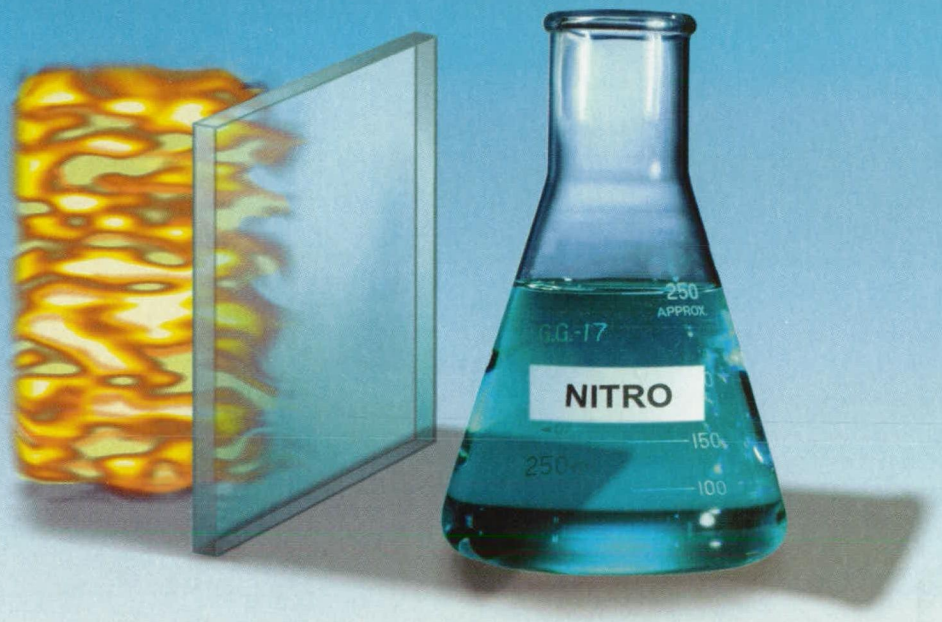


All-Fiber Polarization Controller

Oz Optics, Carp, Ontario, Canada, offers an all-fiber polarization controller that enables the user to convert a single-mode fiber's polarization state, whatever its input, to any desired output polarization. The operating principle is that pressure is applied to a fiber by an adjustable clamp, causing the fiber to behave like an adjustable fractional waveplate. Rotating the clamp causes the waveplate axis to rotate. Extinction ratios of over 35 dB can be routinely achieved, Oz says. The in-line version is designed to work only with 250- and 400-µm jacketed fibers; a pigtailed version with any size cable or fiber and a choice of connectors is also available.

For More Information Circle No. 769

Our Hot Mirrors clearly have explosive advantages.



The line between success and failure is often as thin as a mirror. If your specifications call for a hot mirrors, it's time to call ZC&R. No matter what your need, from off-the-shelf to custom coatings, you'll find all your solutions in one place – ours. And if cold mirrors are more your style, ours stand up to even the toughest test. Our filters always give you superior separation of visible, UV and IR radiation. So don't let your project go up in smoke. For a closer look into our mirrors, call us today. ZC&R. Burning up the competition.

Crystal Clear Hot Mirrors

Guaranteed color neutral even at 5500° K, our crystal clear hot mirrors are perfect for applications such as entertainment lighting, biomedical applications and fiber optics. Guaranteed not to peel, fade or craze.

- Ave. T ≥ 90% at 425-675 nm
- Ave. R ≥ 95% at 750-1150 nm
- Incident angle = 0°

Cold Mirrors

Our cold mirror filters reflect visible light and transmit IR. They are used in a wide variety of products from projectors to fiber optic illuminators.

- Ave. T ≥ 90% at 750-1200 nm
- Ave. R ≥ 95% at 420-650 nm
- Incident angle = 45°

UV Pass Hot Mirror

Designed to block IR and allow visible and UV light to pass through, these hot mirrors are especially well adapted for UV curing of inks, dyes and cements.

- Ave. T ≥ 85% at 245-680 nm
- Ave. T ≥ 86% at 245-400 nm
- Ave. R ≥ 75% at 800-1050 nm
- Incident angle = 0°

Extended Hot Mirrors

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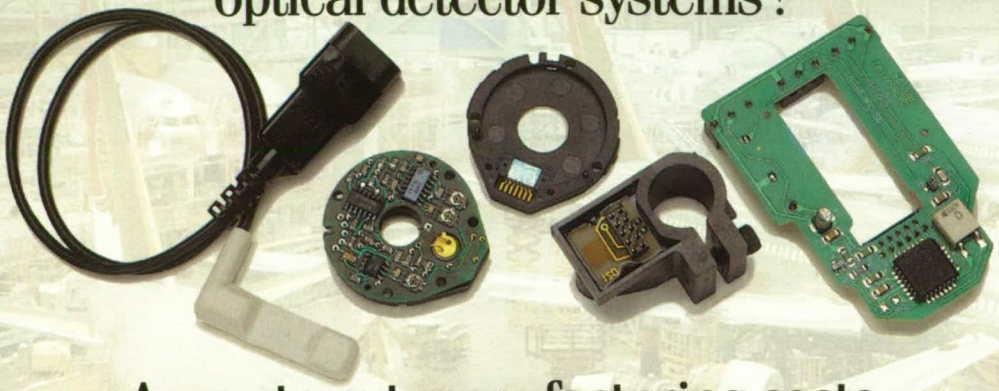
What's behind these optical detector systems?



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Technology Forecasts

Last year, in celebration of NASA's 40th anniversary, we highlighted areas in which NASA has had a major impact in the development of commercial products. As NASA begins its next 40 years, we asked executives at leading companies in many of those areas to provide their views of where technology is heading in the next year — and into the next century.

Engineering Software

Michael Bussler
President & CEO
Algor, Inc.
Pittsburgh, PA
www.algor.com

I see a lot of evolution in 1999. The thing that's new is that in traditional stress analysis, what engineers were trained to do was estimate forces or loads on one hand, and then create stress analyses on parts based on those loads on the other hand. The ideal product would make your CAD solid model and run it like the real thing — with all the loads and stress analyses built in. However, there is no such software today to do that — one that combines load calculations and stress analysis. The ideal product from the engineer's standpoint is one where you can do it all in one model.

One of the things you'll hear about in 1999 is what's called motion load transfer, which is transferring loads from kinematic programs to finite element programs. There are some standards in the works to do that. Many companies announced initiatives for this trend in 1998, and will be going forward with it in 1999. What Algor will be doing in 1999 is a little different than what you'll be hearing from other companies in that we'll be able to bring a CAD model in for FEA and do the entire motion/stress analysis in one shot.

I think in 2000 and beyond, as competitors are able to develop their own intrinsic solutions, partnerships between kinematic program manufacturers and stress analysis program designers will have to break down because the partnerships will have to turn into competitive enterprises. Kinematics people will have to figure out how to incorporate stress analysis, and stress people will have to figure out how to incorporate motion. The trend will be increased integration among these various activities.

Telecommunications

Michael Geller
Chief Technical Officer
Lucent Technologies Government Solutions
Whippany, NJ
www.lucent.com/gov

The worldwide demand for communications services continues to grow rapidly, bringing with it the very real threat of network slowdowns and frequent bottlenecks. But in the years ahead, a network incorporating multigigabit free-space data links could offer a high-capacity adjunct to microwave, optical fiber, and cable in many applications.

This innovative technology is currently in development at Bell Laboratories, and advances have been rapid. Researchers testing a prototype late last year established a world record for no-fiber optical data transmission, sending 2.5 gigabits of information per second, error-free, through 2.4 kilometers of free space. (By comparison, commercial wireless data links, using multiple transmitters, operate at up to only 622 megabits per second.)

The Bell scientists' next objective is the development of 10-gigabit data rates, transmission across greater link distances, and the integration into this technology of wavelength division multiplexing, a method for increasing capacity by transmitting information over multiple wavelengths, or colors, of light.

The experimental technology integrates custom-built telescopes with standard optical transmitters and receivers and a high-power optical amplifier. Data is sent through the air from the transmitting telescope to the receiving telescope and focused onto the core of an optical fiber using coupling optics within the second instrument.

Free-space transmission requires a clear line of sight, so there are some places it cannot be used that fiber can. But with its many potential applications, free-space optical wireless technology, though it isn't intended to replace fiber, will rather complement it.

CAD Software

Dominic Gallello
Vice President, Mechanical Market Group
Autodesk
San Rafael, CA
www.autodesk.com

In CAD, there has been this notion of "mid-range" solid modeling. That phrase has been recoined as "mid-priced" solid modeling. So basically, the mid-price range is now becoming the high end.

A second trend is what I call enterprise connectivity. Mid-range or mid-priced systems were categorized as personal systems for single users. They were not considered process-centric, tied in to the rest of the engineering processes of the company. What I predict is an explosion in the connectivity of these mid-priced systems into the downstream business and manufacturing processes of companies.

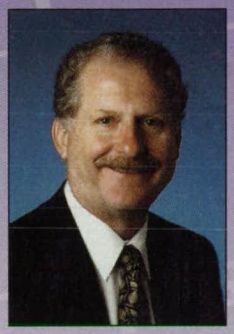
Another trend is 3D digital-content parts libraries. Basically, if you're designing a machine, anywhere from 20% to 80% of the parts in the machine are purchased parts. Previously, you'd look at a manufacturer's handbook, you would find the part you wanted, and you would make either a 2D part or a 3D solid model of it. Working in collaboration with Thomas Publishing, we're going to be offering 3D PartSpec. We're going to be delivering manufacturer's content in 3D over the web, and the most exciting thing is that it's free to our customers because the parts manufacturers are paying for it.

I have no doubt there will be new CAD programs in the marketplace. I think one phenomenon that has changed, however, is that the cost of software developers is frightfully expensive these days. So, you can't compete anymore unless you have volume products that are selling well. One of the issues for customers is the difficulty of having a crowded marketplace. Ten companies can't be in business four years from now with a $5,000 solids modeler, so the stability of a company is an issue for customers.

Test and Measurement

Dr. James Truchard
President and CEO
National Instruments
Austin, TX
www.natinst.com

As PCs become faster, more flexible, and more efficient, the face of engineering and science continues to change. With hardware becoming more compact and highly integrated, labeling individual computer systems and instruments as separate components is more difficult. Connectivity of the two is changing with increased use of Internet and new I/O buses like 1394 and USB. Standardization is also eliminating many compatibility issues.



Recent developments in instrumentation have caused the lines between computer and instrument to blur. Platforms such as PXI™/CompactPCI modular instrumentation package an entire measurement system in a more rugged enclosure with higher performance, greater flexibility, and lower costs.

Internet connectivity is also playing an increased role in the future of the instrumentation industry. Users are beginning to require connectivity for instruments for remote applications, in addition to centralizing data gathering and processing anywhere in the world. Leveraging the technology from the telecommunications market, this may even become a wireless process.

Another trend already forming is industry-wide standardization driven by the computer industry. With the variety of packages and architectures available, vendors have a difficult time switching out components in their test or process systems without affecting system code. Compatibility becomes a real issue. The continued improvements in software and hardware technologies and their integration are converging so engineers and scientists can lower costs, increase productivity, improve connectivity, and share data and information like never before.

Data Acquisition

Tom DeSantis
President
IOtech
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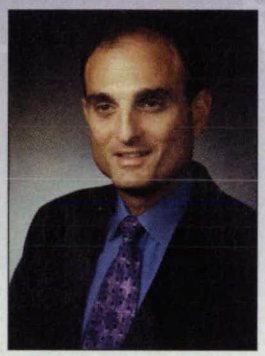
www.iotech.com

There is a market that has developed over the years for portable and notebook PC-based data acquisition. Thus far, everything has been based on the parallel port. That has been the only reasonable way to get things in and out. If you look at new computers coming out, the parallel ports are starting to disappear. So what's happening in the portable PC data acquisition world is that people are going to ask for other interfaces besides parallel, because parallel will ultimately phase itself out. Future products are going to be based on other interfaces.

In the PC plug-in arena, the ISA bus is declining at about 25% per year, and the PCI bus is growing at about 30% per year. So that transition is probably going to continue and maybe accelerate as ISA slots become less popular. There seems to be no end in sight in terms of what CompactPCI might be to the market someday. What I see happening is that the PC data acquisition companies are going to migrate into the CompactPCI world. It might cause the market to really take off dramatically.



There are very few traditional instrumentation companies that have had any impact on the PC-based measurement world. They all use PCs and offer some drivers, but they don't leverage the power of the PC in their products. I predict there is going to be a shakeout of smaller data acquisition companies that have to merge or be acquired to maintain themselves, because the cost to develop the next-generation products is much higher than it ever was.

Electronics

Sassan Khajavi
Microprocessor Business Development Engineer
Toshiba America Electronic Components
Irvine, CA
www.toshiba.com

The continuing proliferation and convergence of mobile and wireless products will be the principal force in driving integrated-circuit (IC) technology in the near future and over the next ten years. This is because the ICs in PDAs (personal digital assistants) and similar products must satisfy multiple challenges. One way our customers can meet all of these requirements is through system-level integration (SLI) technology, also known as "system on a chip."

According to Moore's law, which states that the density and speed of ICs will double every 18 months, in ten years SLI chips will have as many as 10 billion transistors. With so many transistors on one chip, it will be possible to put all the functions needed by a mobile/wireless system onto a single chip. In a decade, however, because of transistor miniaturization (0.05-micron feature size is projected by the year 2010), it will be possible to pack millions of today's real-estate-hungry programmable logic gates onto SLI chips as well.

Enterprise Software

Peter Brooks
Vice President, Manufacturing Engineering Products
Bentley Systems
Exton, PA
www.bentley.com

In 1999, global collaboration in enterprises will become a reality. Engineering projects typically have massive information, hundreds of people, worldwide distribution, and constantly changing models. In 1999, mechanical and manufacturing engineers will manage project information at the component level, rather than the file level. With components, the user can work with as much or as little of a project on a single screen as he or she wants. Components also allow for real-time online collaboration. They enable multiple engineers to view and modify project data simultaneously, with instant conflict resolution. Expect detailed online project histories, as well.

New Tools from The MathWorks

Steven S. Ross

InReview is a new, frequent feature providing hands-on reviews of new and updated software and hardware.

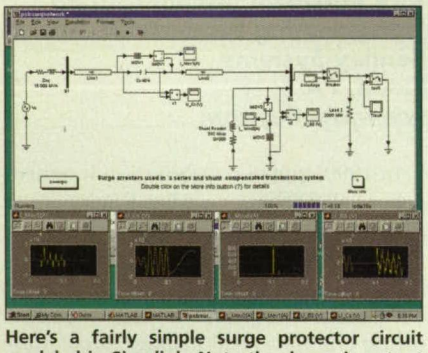
The Math Works will soon release a minor upgrade for its flagship MATLAB computation environment and a major upgrade to its Simulink and Stateflow modeling and simulation environments. We put a Windows version of the betas for Simulink 3.0, Stateflow 2.0, and MATLAB 5.3 through its paces recently.

For prototyping, a good math tool should allow you to:

- Create "quick and dirty" expressions faster than you could with conventional programming languages such as C++.
- Tip you off to possible errors in those expressions.
- Use your existing data in those expressions.
- Provide flexible output, graphically as well as in tables.

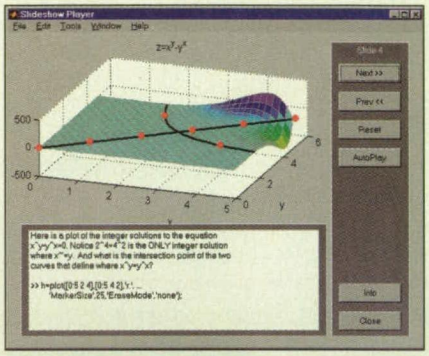
The idea is that you should have excellent command of math, but not necessarily be an excellent computer programmer, adept in low-level languages such as C, C++, or Fortran.

There are lots of products that can do this basic set of tasks. The best one for you will depend on your computational needs (not all products can handle all math problems), work requirements (some compute big problems faster), and the way you think about numeric problems. I gravitate toward TK-Solver, for instance, because it is the package I started with in 1983 and because it handles expressions without transpositions. That reduces coding time, even though the final expressions may run more slowly than the equivalent in competing products.



Here's a fairly simple surge protector circuit modeled in Simulink. Note the dynamic output showing in the four windows below.

MATLAB does the computations, and with Simulink it does a whole lot more. You can combine blocks of expressions into functional simulations with Simulink, or into complex control logic models with Simulink's Stateflow add-on. It is easy to move from one to the other.



MATLAB has sophisticated ways of displaying functions. The graph and the interactive dialog box that displays it are all constructed with program tools.

This makes the MATLAB/Simulink combo particularly useful for designing and validating complex control systems — everything from automobile brakes, to jet aircraft, to chemical plants. It includes more than 500 math, statistical and engineering functions, leaning heavily to matrix math methods. MATLAB and Simulink also have slick ways to generate click-and-go on-screen interfaces.

MATLAB itself is particularly flexible because it was originally designed for handling matrices (arrays). The name comes from "matrix laboratory," in fact. MATLAB notation is straightforward if you are used to matrix math and Visual Basic or C++. A calculation resulting in a log or square root of a negative number, for instance, is displayed appropriately, without error message.

But as a pure computation tool, MATLAB's ease of use is sometimes not quite as intuitive as some competitors'. The shortcoming is pretty much overcome if you spring for the $595 Symbolic Math toolbox, which includes the Maple kernel (prices are higher for workstations). Other toolboxes at this price (each) include statistics, partial differential equations, and signal processing. Toolboxes at $895 include fuzzy logic, more symbolic math (the full Maple suite), and a compiler to turn MATLAB (not Simulink) programs into stand-alone applications.

If you're willing to pay $9,995 for the Real-Time Workshop compiler (Windows or UNIX only), MATLAB/Simulink expressions usually can be compiled in C or Ada and linked with other code your organization may already have created. The upcoming release also improves Real-Time Workshop and the compiler toolbox to handle all Simulink expressions.

Simulink, the key MATLAB add-on, is a delight. You assemble a control system, for instance, with blocks representing motors, relays, hydraulics, triggering functions, and so forth. You connect the blocks with arrows and test interactively. You can (and probably will) modify various blocks for your purposes. You can easily model subsystems, and then combine them. Version 3.0, which we reviewed in beta, has much-improved navigation tools for browsing really big systems, and easier ways to modify blocks. There's also a nice dialog box approach for entering parameters, and a new set of blocks that look like dials and gauges. These are great when others with limited Simulink training have to use your preliminary models.

Stateflow is an add-on to Simulink. Stateflow diagrams show "states" (descriptions of the system's behavior) and "transitions" between one state and another. Transitions can branch or exist in parallel. It is not available for the Macintosh. The new version, 2.0, has a faster debugger and better navigation tools.

Steven S. Ross is associate professor of journalism at Columbia University, New York, NY. He has a BS in physics from Rensselaer Polytechnic Institute, and has authored technical papers in the areas of quality control and statistics. Ross has authored three commercial software packages, including a units conversion program and an engineering calculations program. Prior to joining the Columbia faculty, he served as president of CCM, a developer of C-language graphics tools and educational software.

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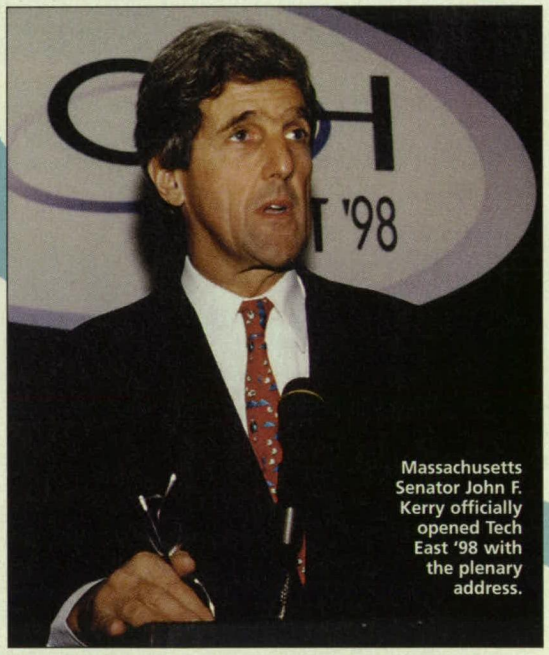
TECH EAST '98

Technology Transfer—Today for Tomorrow

Launched by Senator John Kerry, this mega-event drew design and manufacturing engineers and entrepreneurs from all over the New England high-tech corridor.

Tech East '98, held November 3-5, 1998, at Boston's Hynes Convention Center, combined six major technology events all under one roof: Technology 2008, America's premier showcase of new and next-generation technologies available for commercialization; New England Design & Manufacturing Expo, featuring the latest products and services to help engineers meet their design, prototyping, and production challenges; Small Business Tech Expo, showcasing resources and technologies to launch new products and partnerships; National SBIR Conference, where business managers learn how to tap into the billion-dollar government R&D grant program; Photonics East, the Northeast's only optics and photonics exhibition; and Electronic Imaging International, the East Coast's premier annual imaging exhibition.



Massachusetts Senator John F. Kerry officially opened Tech East '98 with the plenary address.

On Tuesday, November 3, Tech East '98 was officially opened by Massachusetts Senator John F. Kerry. The top-ranking Democrat on the Senate Small Business Committee, and a member of the Committee on Commerce, Science, and Transportation, Kerry is in his third term as Senator. In his plenary address, he focused on the success of the Small Business Innovation Research (SBIR) program, and what small businesses need to do to advance the program further.

"The frontiers are changing so rapidly for all of us that it just underscores how difficult it is in business to have a business plan that lasts, and that cannot be subject to enormous changes in a very rapid period of time. All of you are involved in many of those efforts," said the Senator.

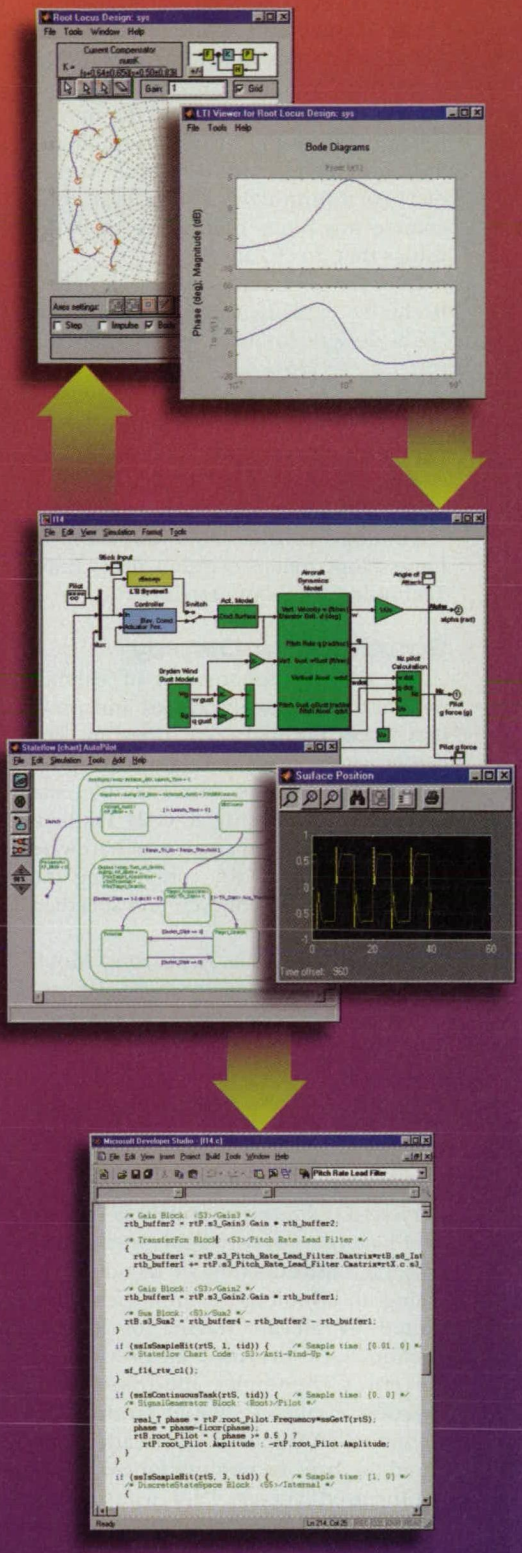
"Let me share a picture with you of where this program is today and where we're going," Senator Kerry continued. "First of all, we should all be very proud of the fact that since 1983, when this program began, the results have really been dramatic for small, innovative, creative, energetic entrepreneurial entities that have wanted to push the technology curve. And since 1983, some 16,000 small, high-technology firms have received more than 46,000 SBIR awards through last year, totaling $7.5 billion. We recognize that there have been tremendous spinoffs out of this. The most obvious and tangible are the jobs."

According to Senator Kerry, "Twenty-five percent of SBIR projects have become products or services that are sold in the marketplace. Last year, small, high-technology companies accounted for nearly one-third of all the jobs in the high-technology sector. That is exactly the kind of energy that we wanted to create with this program. Small business is critical to the country's technology sector. Small companies employ 3.7 million researchers, versus 3.2 million employed by larger technology companies."

Underscoring the importance of the country's small business programs, Senator Kerry asked the audience of technology professionals to join his efforts in advancing small business in all areas of the country. "I think (the SBIR program) provides a very strong incentive for small businesses to join with universities and other size businesses, and share technology and research in a way that helps accelerate creative effort. My hope is that you'll help us. Whatever state you come from, you need to be part of the communication process to your congressmen and to your senators to help them understand how this (small business program) works."

At the Tech East '98 ceremony, Stuart C. Karon (left), director of government programs for American Superconductor Inc., accepts the certificate for Grand Winner of the 1998 SBIR Technology of the Year Award from Robert S. Clark, senior editor of *NASA Tech Briefs*.

The small business program worked well for the winners of the 1998 SBIR Technology of the Year Awards, which were presented at a ceremony on the final day of the conference. These awards recognize companies that have developed important commercial products and services through the federal government's



Flight control system example

Our integrated control design solution allows you to move smoothly through the stages of your design process. Use MATLAB for data analysis and algorithm development (top), Simulink and Stateflow for both dynamic and event-driven simulation (middle), and Real-Time Workshop for generating prototype code (bottom).

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SBIR program, the nation's largest source of early-stage, high-risk technology financing to bolster America's competitive advantage.

The 1998 Grand Winner was American Superconductor of Westborough, MA, for its development of advanced high-temperature superconducting materials and devices used in a wide array of commercial and military applications, including DC/DC converters for mobile radar, minesweeping equipment, acoustic transducers, actuators, and motors. American Superconductor has received SBIR funding from the Department of Energy, the Air Force, the Office of Naval Research, and the Ballistic Missile Defense Organization (BMDO).

The winners of the 1998 SBIR Technology of the Year awards: from left, Stuart C. Karon, director of government programs for American Superconductor; Malcolm McGeoch, manager of PLEX LLC; Jack Jewell, chief technical officer of Picolight Inc.; Pradeep Gandhi, CEO of Ormet Corp.; and Suresh Menon and Stephanie A. Vierkötter, research scientists for Quantum Magnetics.

Winners were also named in four leading technical categories. In electronics and computing, Picolight Inc. of Boulder, CO, won for creating a new generation of vertical cavity surface-emitting lasers to be used in high-speed fiber data communications such as Gigabit Ethernet and Fibre-Channel. Picolight developed the devices with the aid of a BMDO SBIR grant.

In the industrial and manufacturing category, PLEX LLC of Cambridge, MA, was chosen for producing the first commercial high-power laboratory source of soft x-ray light, suitable for extreme ultraviolet lithography, microscopy, and materials studies. Again BMDO provided funding.

The winner for materials was Ormet Corp. of Carlsbad, CA, for a family of novel conductive composite materials that sinter at low temperatures. Developed through an Army SBIR grant, the materials have many applications in electromagnetic shielding, including printed circuit boards.

In the final category of sensors and instrumentation, Quantum Magnetics of San Diego, CA, was recognized for an innovative method of monitoring strain long-term in a variety of structures using nuclear quadrupole resonance. The non-contact strain gauge, developed with BMDO SBIR funding, allows for early flaw detection and longer-lasting, lower-cost composite structures.

An independent panel of judges viewed and graded each nomination based on its technological novelty and commercial or industrial applications. The fifth annual awards were sponsored by the Technology Utilization Foundation in cooperation with all federal agencies and departments that participate in the SBIR program.

Marketing Technology

Delivering the Tech East '98 keynote address was Dr. Jim Taylor, chief marketing officer of Iomega Corp. and co-author of the best-selling book *500 Year Delta*. Dr. Taylor directs all worldwide marketing for Iomega Corp., manufacturer of the popular Zip™ and Jaz™ drives for data storage. A nationally-renowned speaker, Dr. Taylor has appeared on "The Today Show," "Oprah," and CNN.

Discussing themes from his book, Taylor focused on the effects of social change on marketing and business management, particularly in the technology field. "The first reaction of most people exposed to a new technology is horrified negation," said Taylor. "In other words, 'I don't like it because its existence is a criticism to my own pres-


The Tech East '98 keynote address was delivered by Dr. Jim Taylor of Iomega Corp.

ence.' We then move into a period of negation without horror. In other words, 'It's a bad idea, but I'm not afraid.' From that, we move to a stage of passive acceptance. 'It's a bad idea for me, but it's good for everybody else.' And finally, the average individual adopts acceptance with enthusiasm — "It can change my life not only in a functional way, but in a meaningful way.'"

For technology to succeed, said Taylor, we have to move beyond the narrow limits of the value of our technologies into a wider question of "what does it do?" He continued, "Things that don't change are more interesting than the things that do change."

In order to market technologies effectively, he explained, people must ask, "How does technology amuse? How is it interesting? How does it make a difference for people who are curious?" According to Taylor, "the reason technology has a marketplace at all on the investment capital side is that we have hope. The most important issue facing technology is the communication of hope. Hope means certainty every time. Technology is about certainty."

Solutions on Display

The 100,000 square feet of exhibits demonstrated new inventions and products across the high-tech spectrum. The centerpiece of the New England Design & Manufacturing Expo, for example, was the Rapid Prototyping & CAD Pavilion, which demonstrated an array of hardware and software tools for compressing the product development cycle and speeding the time to market.

Exhibitors such as Armstrong Mold, ARRK Product Development Group, Agile Software, Stratasys, Z Corporation, Sanders Design, and Coherent displayed everything from CAD/CAM software, to rapid prototyping systems and digitizers, to laser systems and model-making services.

Complementing the exhibit pavilion was a series of tutorials and short courses dealing with various rapid prototyping subjects. "Introduction to Rapid Prototyping and Tooling Technologies," presented by Merlin Warner of Warner Technologies, provided an overview of current technologies illustrated with practical examples. "Rapid Product Development: Advances & Applications" focused on three techniques for compressing the product cycle. Paul Armstrong of Armstrong Mold shared "Benefits of CAD in Molding and Casting." "Using Rapid Prototyping (RP) to Develop RP Systems," presented by Jim Comb of Stratasys, described how the company has employed its FDM rapid prototyping technology to create its new Quantum® RP system. Finally, "Innovative Electroformed Tools" was presented by Paul Jacobs of Express Tool, which has developed a process to reduce cycle times, using composite mold construction and conformal cooling technologies.

Commercialization Opportunities

Reactive-Insulator SiC-Based Schottky Diodes as Gas Sensors

Improved silicon carbide-based Schottky diodes are being developed for detecting hydrocarbon and nitrogen oxide gases at high temperatures. These gas sensors demonstrate improved sensitivity in monitoring engine-exhaust emissions and other hazardous gases emitted in low concentrations.
(See page 30.)

Dual-Function Microelectronic Sensors

These integrated-circuit image sensors can produce images in visible, infrared, or both spectra. A number of useful applications are envisioned in scientific and industrial areas, among which are noncontact measurements of temperature distributions and early detection of developing tumors.
(See page 33.)

Fabry-Perot Fiber-Optic Temperature Sensor

This very rugged design can be used in monitoring and control of advanced aircraft engines, conventional and nuclear powerplants, industrial plants, and other systems where conditions may be too severe for electronic temperature sensors.
(See page 34.)

Integrated Electrochemical Sulfur Dioxide Sensors

These sensors are being developed for measuring concentrations of sulfur dioxide in gas mixtures. Originally conceived for sensing sulfur dioxide in volcanic gases, these sensors can also be used for monitoring sulfur dioxide in gases emitted from metallurgical processing, refining of petroleum, and burning of coal.
(See page 36.)

Solar-Cell System With High Conversion Efficiency

A concept of getting conversion efficiencies as high as 50 percent involves concentration and spectral dispersion of solar energy and the use of several types of solar photovoltaic cells, each placed at the optimum location in the spectrum.
(See page 43.)

Luneberg Lenses Made of Open-Cell Polyurethane Foams

These microwave lenses can be made of open-celled elastomeric foams, which would make them more durable, cheaper, and lighter than lenses made from conventional closed-cell materials.
(See page 44.)

Packaging Electronic Circuits in Multi-Board Modules

A new scheme cost-effectively combines digital electronic circuits into dense, lightweight packages, within which high-speed signals can be transmitted readily in three-dimensional conductive paths with minimal lengths.
(See page 45.)

NASA Optimizes Satellite Reaction Wheel With Random Vibration Software

ALGOR random vibration stress analysis software

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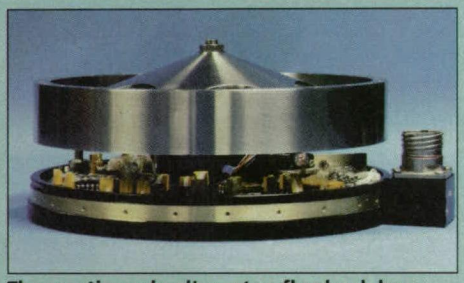
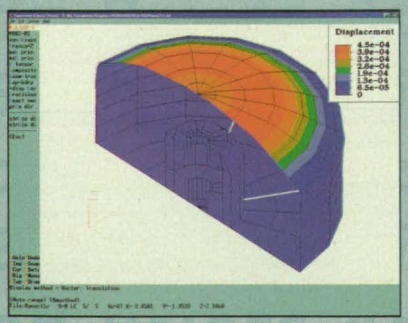
NASA scientists rely on reaction wheels to maneuver observation satellites in space. Based on information gathered by sensors, four reaction wheels position the satellite to face constellations of interest. The reaction wheels must withstand rocket launch vibrations to operate effectively in orbit. Engineers at NASA's Goddard Space Flight Center in Greenbelt, MD, used random vibration stress analysis software from ALGOR, Inc. to test the structural integrity of a redesigned reaction wheel that can position satellites more quickly.



The reaction wheel's motor, flywheel, bearings, PC board, and electronic parts attach to the base of an outer aluminum housing (shown with the top cover removed) that protects the components from radiation and the pressure differential in orbit.

NASA simulated vibration forces during a rocket launch and analyzed deflection in the reaction wheel's outer housing structure. NASA then optimized the housing's design on the computer to reduce deflection that would otherwise cause the reaction wheel to fail.

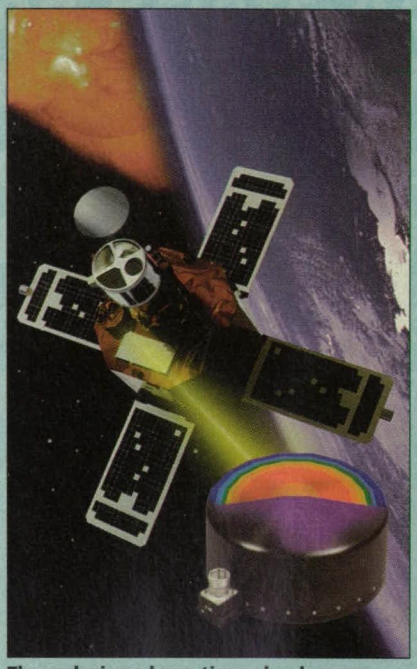
A reaction wheel is an actuator that is part of the satellite's Attitude Control System (ACS). The reaction wheel changes the satellite's position based on torque commands issued by the satellite's exterior sensors. Each reaction wheel is comprised of a motor, flywheel, bearings, and a printed circuit (PC) board that supports its electronics parts. The PC board is attached to ribs at the base of an outer housing, the component that protects the reaction wheel's parts from radiation and the pressure differential in orbit.



This final ALGOR model of the reaction wheel's housing illustrates the response due to random vibration. The base has been constrained in all directions to replicate its attachment to the satellite. One-half of the model is shown for better viewing. The white lines at the housing's base represent beam elements that NASA used to represent the ribs.

NASA redesigned its reaction wheel to maneuver satellites more quickly. Engineers enlarged the motor, bearings, and flywheel to provide more torque and momentum storage, and altered the aluminum housing to fit them. They first used ALGOR's linear static stress analysis software to optimize the geometry of the revised flywheel and housing component. Then they used ALGOR's random vibration stress analysis software to analyze the housing component's deflection during the 8- to 12-minute launch from Earth.

To operate effectively during the reaction wheel's three-year life span, its outer housing must not deflect enough during launch to fracture the solder joints that attach electronic parts to the PC board. The reaction wheel would then lose functionality. The housing also must not deflect against the PC board or rotating flywheel, causing them to malfunction. NASA used ALGOR's random vibration stress analysis software to determine the housing's response to simulated launch vibration loads.



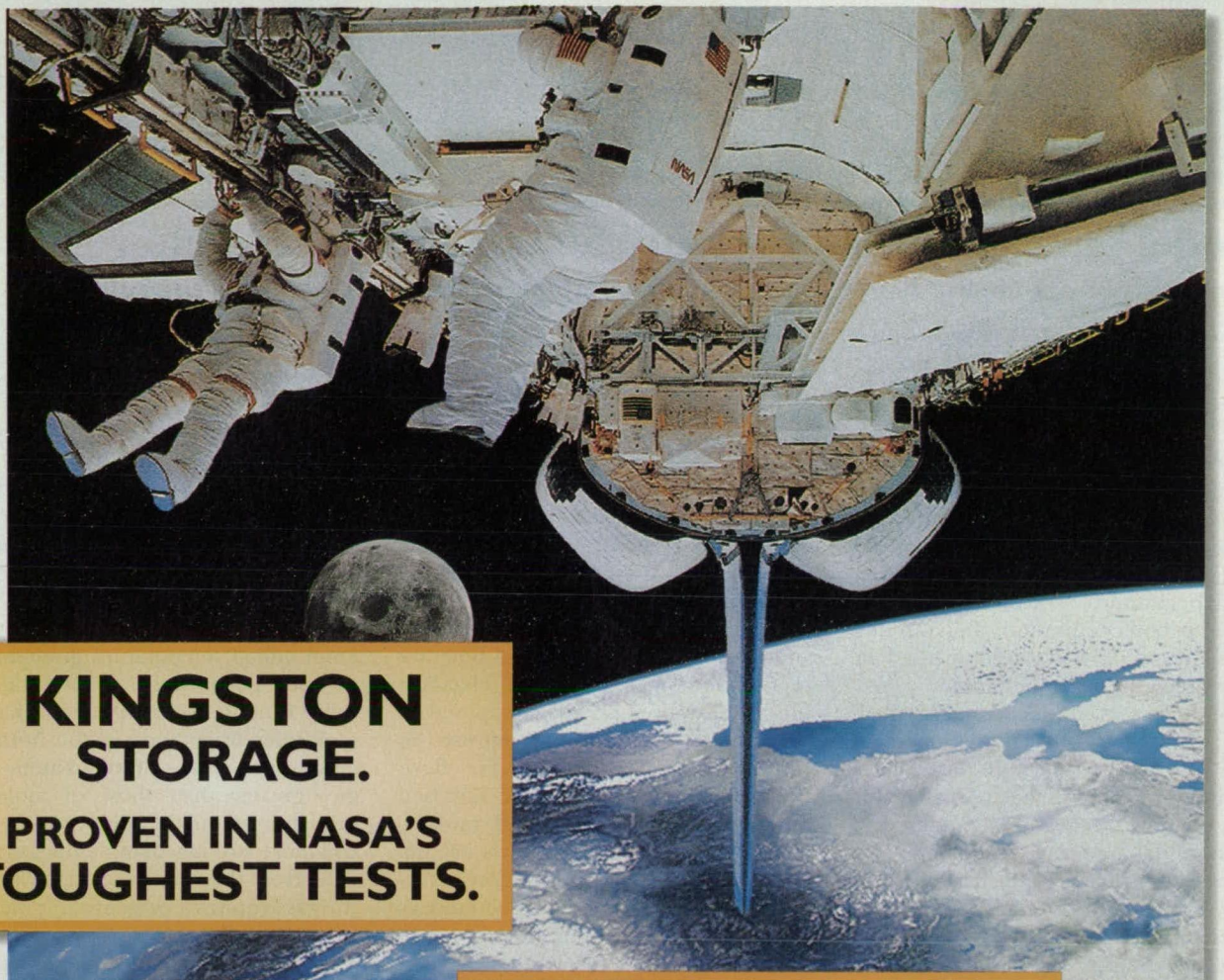
The redesigned reaction wheels were launched successfully on the TRACE satellite in April 1998, a satellite mission studying the Sun's coronal region.

NASA engineers designed a 3D finite element model of the housing with ALGOR's Superdraw program. They used beam elements to represent six radial ribs at the base of the housing and a combination of 3D plate elements and 3D brick elements for the remainder of the housing model.

After conducting a modal analysis with ALGOR software to determine the housing's natural frequencies and modes of vibration, NASA performed a random vibration analysis that simulated actual rocket launch vibration levels. Engineers applied a 14.1-G root mean square (RMS) acceleration to the model, a combination of the accelerations experienced in the X, Y, and Z directions at one time. The first set of analysis results showed excessive deflection within the housing's radial ribs, indicating that the ribs would fracture the solder joints. NASA thickened the radial ribs to increase their stiffness.

After three iterations, NASA created a physical prototype and affixed it to a vibration machine in its laboratory that simulated 14.1 Gs (RMS) in the X, Y, and Z directions. The physical prototype test results correlated closely with ALGOR software results. The redesigned reaction wheels were launched successfully on the Transition Region and Coronal Explorer (TRACE) satellite in April 1998, a satellite mission that is studying the Sun's coronal region. The wheels also are scheduled to operate on the Submillimeter Wave Astronomy Satellite (SWAS) and the Wide Field Infrared Explorer (WIRE). The expeditions will explore multiple star fields to give scientists a better understanding of star formation.

For More Information Circle No. 746



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Model of Response of Pressure Sensor in Rarefied Flow

Responses of pneumatic sensor systems can be evaluated over ranges of flow conditions.

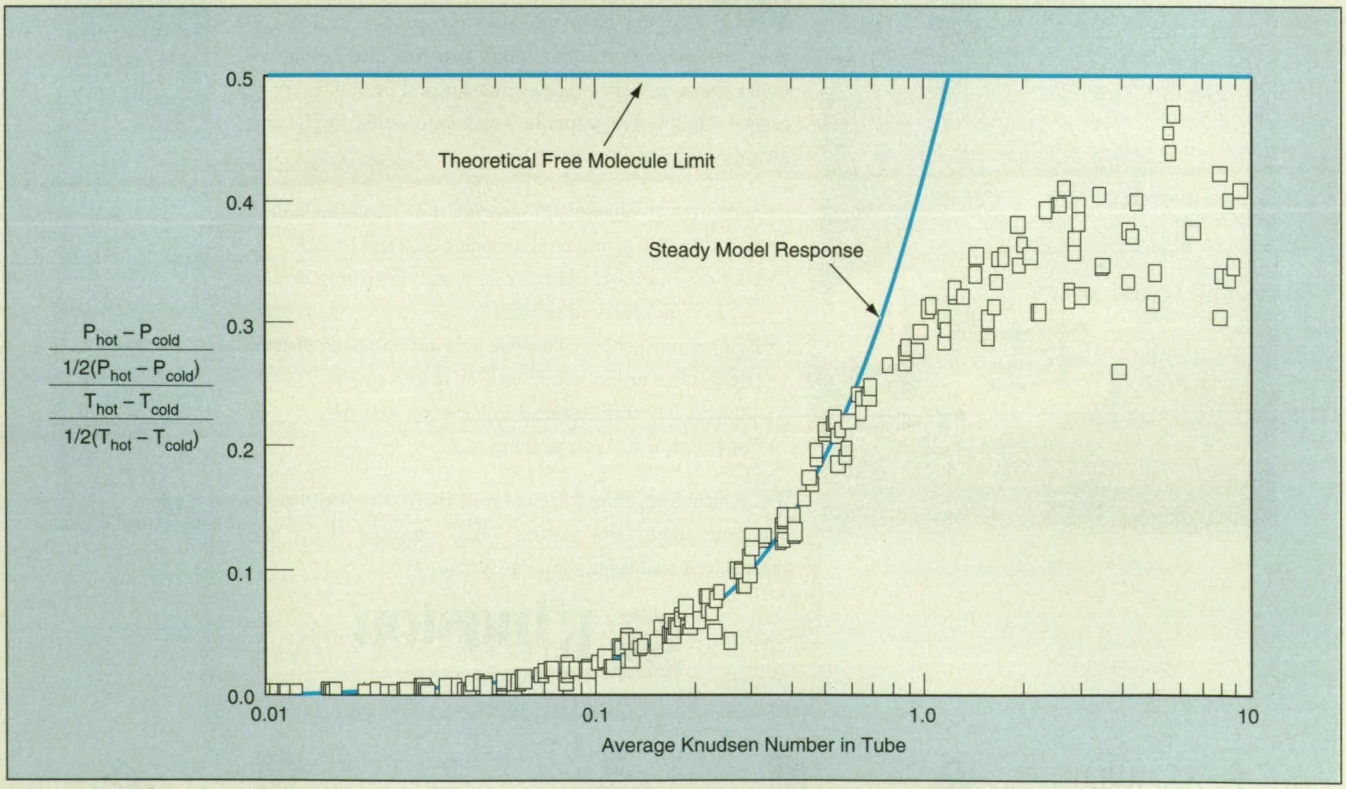
Dryden Flight Research Center, Edwards, California

A mathematical model represents the dynamic response of a pressure sensor that (a) comprises a transducer connected to a pressure-sensing port via a pneumatic tube and (b) is operated under flow conditions like those expected to be encountered on advanced hypersonic aerospace vehicles operating at high altitudes. The model is applicable to both continuum and rarefied flows, including flows accompanied by large gradients of temperature.

Heretofore, the influences of rarefied-flow phenomena on the responses of such a pressure sensor were not well understood. In the presence of hypersonic flow, not only are measurements affected by nominal spectral distortion and acoustical resonance, but in addition, a large temperature gradient induced by boundary-layer heating can induce a molecular transpiration effect, in which gas molecules adjacent to the tube wall creep from the cold end of the tube to the hot end. Furthermore, at low pressure typical of operation at very high altitude, the gas in the tube becomes so rarefied that the flow slips at the tube wall. The present mathematical model was developed to enable evaluation of the dynamic response (the frequency response) under these flow conditions.

The model was derived from the equations of energy, continuity, momentum, and state. Effects of rarefied flow are represented by letting fluid elements slip at the tube wall; this is opposed to the classical "no-slip" condition used in continuum flow mechanics. For flows characterized by values of the Knudsen number between 0.01 and 1.0, molecular and continuum flow effects are important. Under these conditions, free-stream flow away from the wall boundary is identical to continuum flow; however, at the wall, the fluid elements do not stick to wall as they would in continuum flow. Instead, fluid elements slip along the wall — hence the name "slip-flow" regime.

Under slip-flow conditions, the fluid velocity at the wall boundary can be decomposed into two parts: the slip velocity and the thermomolecular "creep" velocity. The slip velocity is proportional to the shear stress at the wall and is a result of reduced viscosity in a rarified fluid. The creep velocity is proportional to the longitudinal temperature gradient and inversely proportional to the local pressure. Kinetic theory predicts that gas molecules originating in the hotter region of the tube — having kinetic energies greater than those of molecules originating from the colder region — recoil more strongly than do the gas molecules from the colder region. As a result, the gas acquires a tangential momentum from the colder toward the hotter region. This net momentum gain causes the gas molecules at the wall to creep from the cold to the hot end of the tube.



A **Comparison of Steady-State Model Response to Measured Values** of nondimensional steady response parameter for rarefied flow conditions shows that the model is valid for Knudsen numbers up to about 0.6 and is valid for most of the slip-flow regime.

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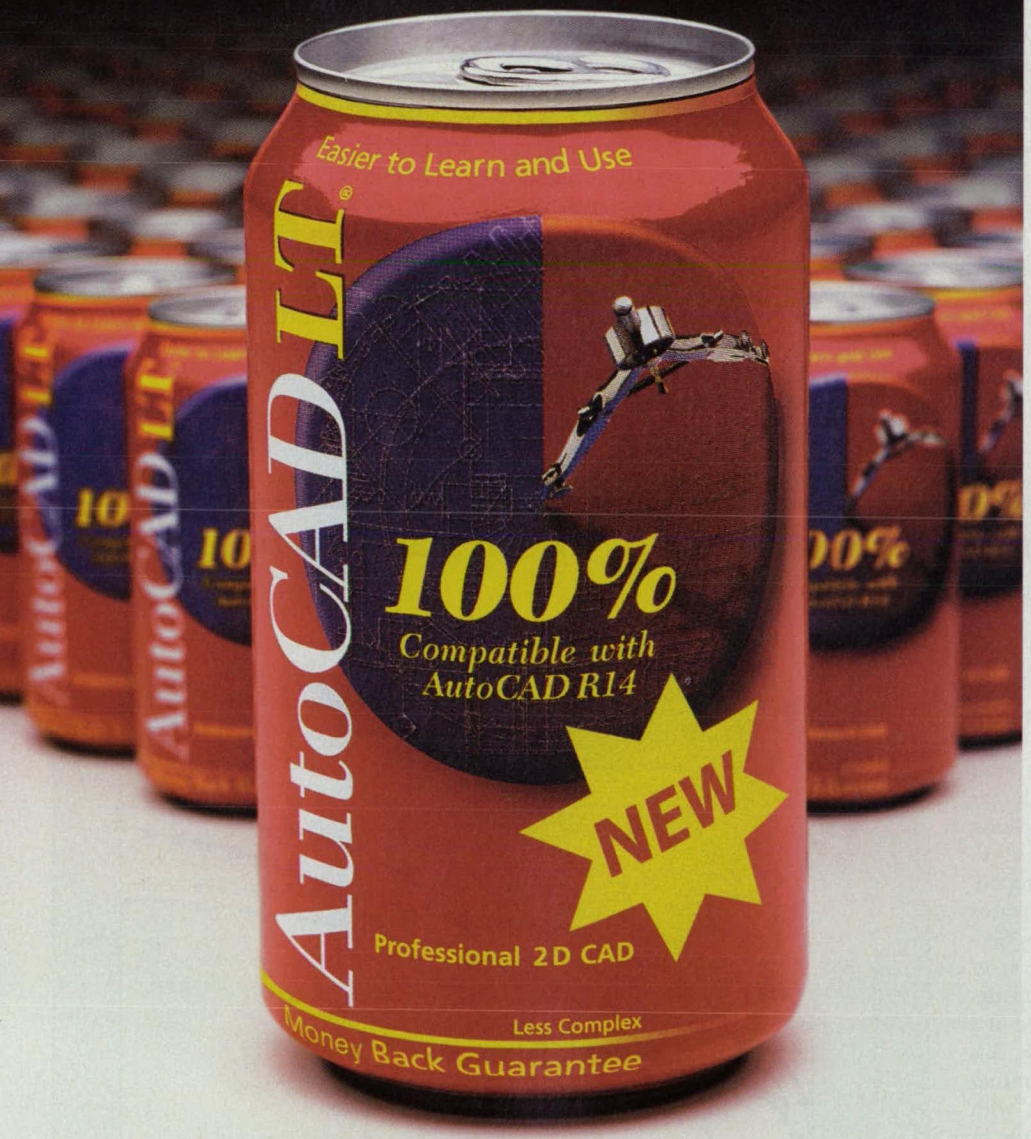

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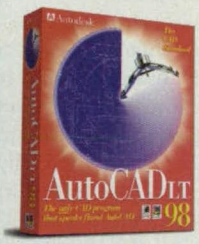

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To balance this creep, gas molecules in the center of the tube must migrate toward the colder end of the tube. The result of this "opposing flow equilibrium" is the establishment of a static pressure gradient such that cold region of the tube reads lower than the hot region and there is no net cross-sectional flow in the tube. At the wall boundary, the velocity is the sum of the slip and creep velocities. Other than this modification, the classical equations of fluid motion apply in this flow regime.

The equations of motion are linearized by use of small perturbations. The energy equation is decoupled from the momentum and continuity equations, assuming that the longitudinal wave expansion process within the tube is polytropic—that is, behaves according to a simple energy submodel that relates pressure, temperature, and density. The assumption of polytropic flow makes it possible to decouple the energy equation from the equations of momentum and continuity, without loss of generality. The boundary-value equations are radially averaged and solved with the help of the assumption that gas properties remain constant along the length of the tube. The resulting fundamental solution is used as a building block for complex situations in which fluid properties and tubing geometries vary longitudinally. The problem is solved recursively, starting at the transducer end and working toward the surface end of the tube. Using recursive formulas, solutions for arbitrary geometries and longitudinal temperature profiles are constructed.

The steady-state behavior of the model is analyzed by applying the final-value theorem to the recursive equation. The resulting expression is nondimensionalized and written as a function of the Knudsen number. Since it is extremely difficult to conduct controlled dynamic experiments under rarefied-flow conditions, the steady-state analysis is extremely important because it is the only feasible means of evaluating the range of validity of the slip-flow assumptions used in deriving the model.

Steady-state-response tests were performed under rarefied-flow conditions to verify the slip-flow assumptions used in deriving the boundary-value equations, and to establish a regime of validity for the model; the results (see figure) showed that the model is valid for Knudsen numbers up to about 0.6, and is valid for most of the slip-flow regime.

The model contributes to understanding of flow behavior at the limits of the continuum flow regime. It will enable instrumentation designers to evaluate the responses of pneumatic systems over a wide range of flow conditions in a general and unified way, without having to resort to *ad hoc* or special-case models. Potential nonaerospace applications of the model include prediction of the behaviors of fluids in micromachined systems, wherein the mean free paths of the working fluids are of the order of channel widths; and prediction of flows of highly viscous fluids for which Knudsen numbers can be sizeable under nonrarefied-flow conditions.

This work was done by Stephen A. Whitmore of **Dryden Flight Research Center** *and Brian Petersen of the University of California, Los Angeles. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category. DRC-95-34*

Reactive-Insulator SiC-Based Schottky Diodes as Gas Sensors

High-temperature gas sensors are being developed.

Lewis Research Center, Cleveland, Ohio

Improved silicon carbide-based Schottky diodes are undergoing development for use in detecting hydrocarbon (C_xH_y) and nitrogen oxide (NO_x) gases at high temperatures. In comparison with gas sensors of other types, Schottky-diode gas sensors exhibit relatively high sensitivity — an advantage for monitoring engine-exhaust emissions and hazardous gases emitted in low concentrations. SiC-based Schottky diodes can function at temperatures too high for Si-based devices; beyond the obvious advantage of a wider operating-temperature range, this opens the possibility of incorporating into sensors materials that react with C_xH_y and NO_x at high temperatures in ways that enhance sensitivity, selectivity, and/or stability.

The simplest Schottky-diode gas sensor is a metal/semiconductor (MS) device; it includes an electrode made of a catalytic metal (in this case, Pd) deposited on a semiconductor (in this case, SiC). For hydrogen and hydrocarbons, the gas dissociates on the exposed surface of the metal and diffuses to the metal/semiconductor or metal/insula-

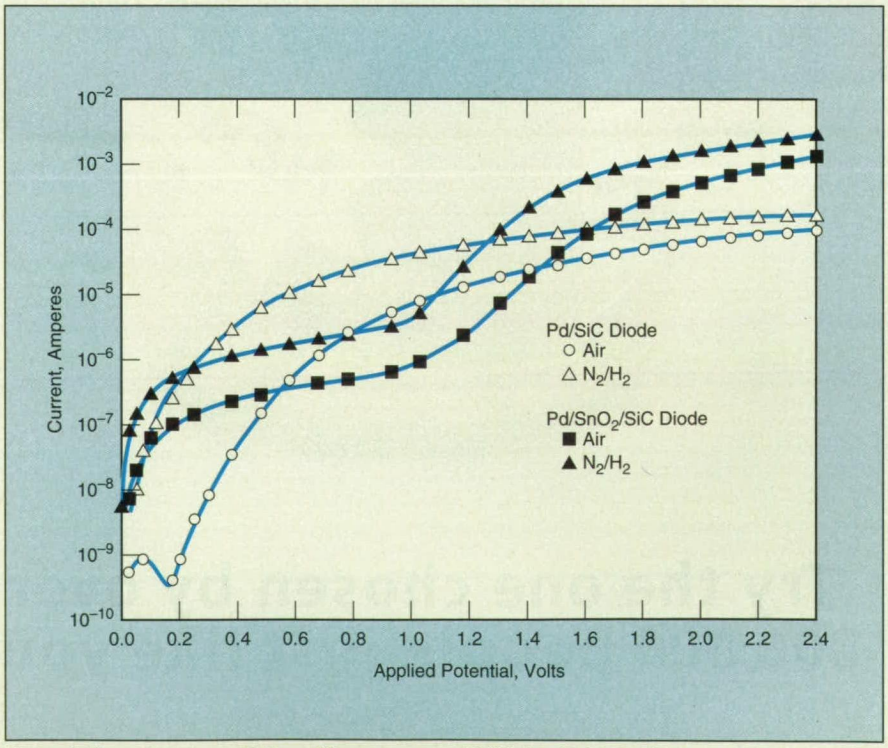

Figure 1. These **Current-vs.-Voltage Measurements** of Pd/SiC and Pd/SnO_2/SiC gas-sensing diodes show how the SnO_2 layer alters the electrical characteristics and the response to H_2 gas.

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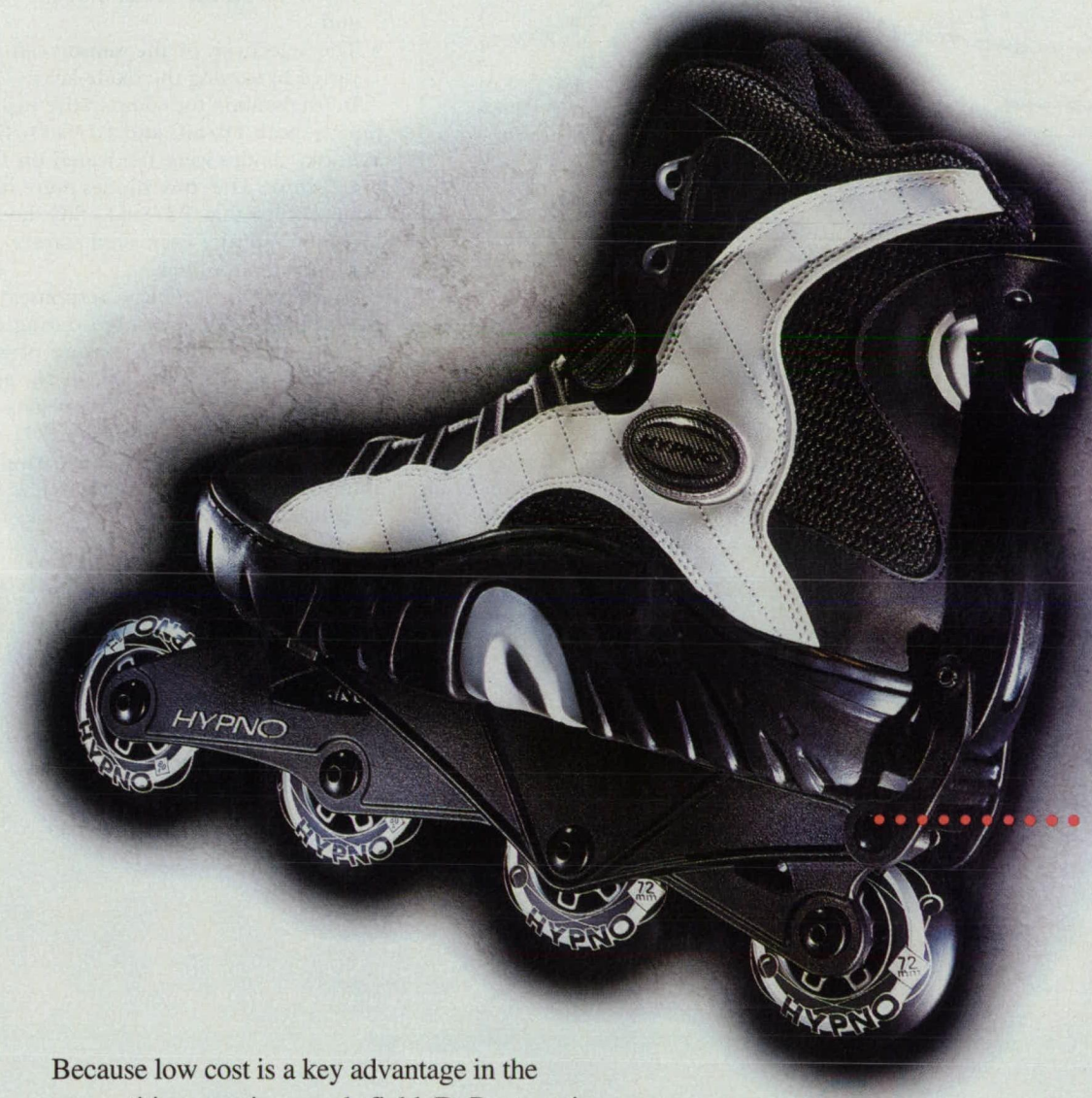

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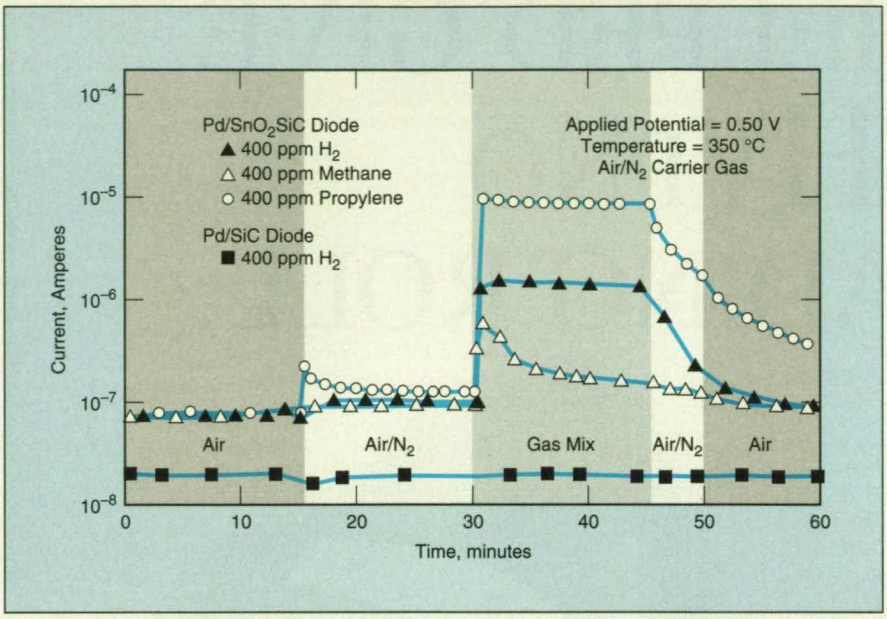

Figure 2. These **Current Responses at Constant Voltage** measured on thermally aged Pd/SiC and Pd/SnO2/SiC diodes show that the SnO2 layer had prevented or at least reduced the degradation effected by the aging process.

tor interface, forming a dipole layer that changes the electronic properties of the Schottky diode in proportion to the amount of the gas.

The SiC-based Schottky-diode gas sensors that are the subjects of the present development efforts are metal/reactive-insulator/semiconductor (MRIS) devices. In contrast to standard metal/insulator/semiconductor (MIS) structures, the insulations in a MRIS structure are chosen for their reactivity to the gas of interest. In the fabrication of an MRIS device, an electrically insulating layer of metal oxide (for example, SnO_2) is incorporated between the catalytic electrode and the SiC semiconductor layer to obtain the advantageous high-temperature characteristics mentioned above. More specifically:

- Sensitivity is increased because the C_xH_y or NO_x gas reacts with the reactive oxide insulating layer as well as with the catalytic metal;
- The sensor can be made more stable in that the oxide layer can act as a barrier between the metal and the SiC; and
- The selectivity of the sensor can be varied by varying the oxide layer.

In preparation for comparative experiments, both Pd/SiC and Pd/SnO_2/SiC Schottky diodes were fabricated on the same chip. The two diodes were the same except that Pd/SnO_2/SiC diodes included sputter-deposited layers of SnO_2 about 50 Å thick.

The current-vs.-voltage responses of these diodes were measured during exposures to air and to a mixture of 400 parts per million (ppm) H_2 in N_2, at a temperature of 350 °C. The results of these measurements (see Figure 1) on the Pd/SnO_2/SiC diode show parallel shunt resistance at potentials below 1.0 V; proceeding upward from 1.0 V, the

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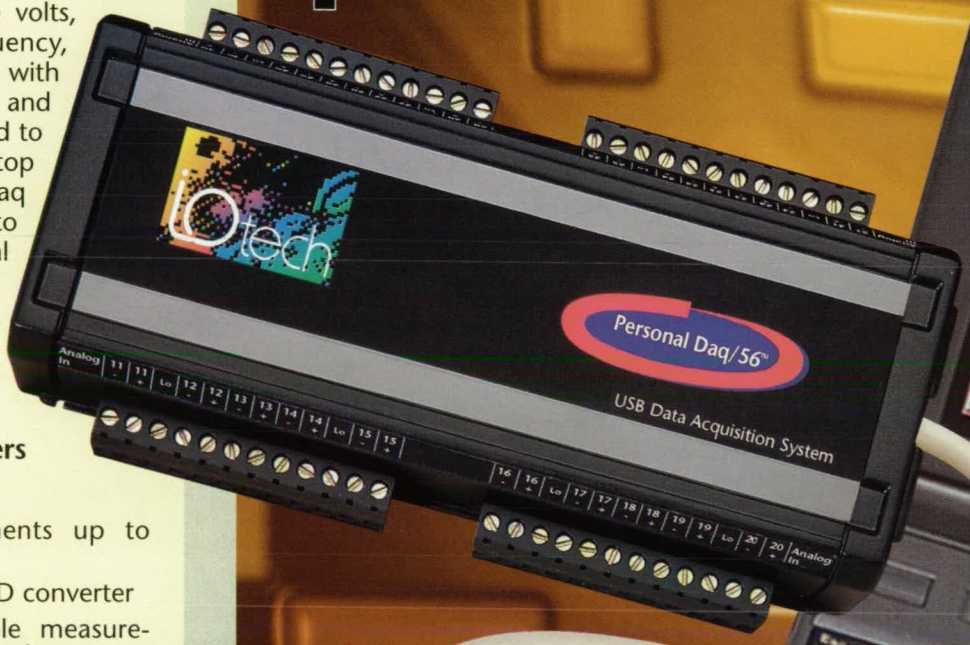

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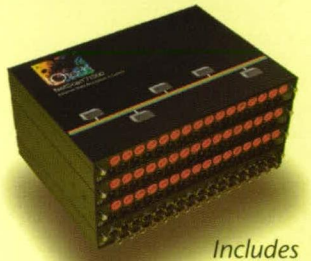

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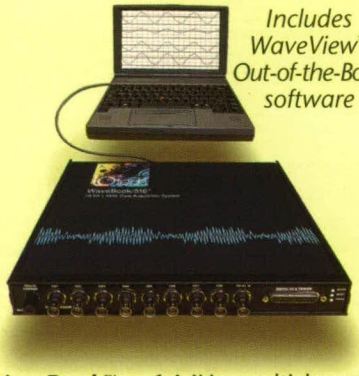

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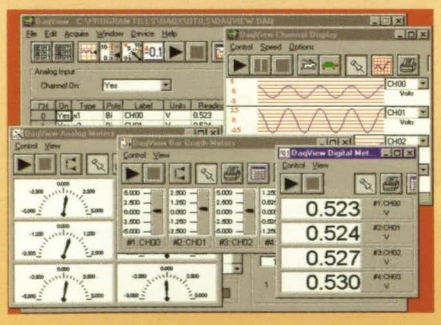

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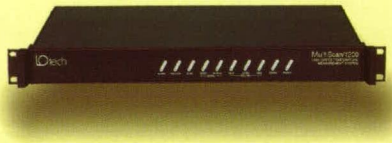

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data show exponential Schottky behavior at first, with series resistance increasing and beginning to dominate at the high end of the voltage range. Analysis of the exponential portion of the curve leads to the conclusion that the SnO_2 layer increased the Schottky barrier height. The effect of the 400 ppm H_2 in N_2 was to increase the current at a given voltage. One of the effects of the SnO_2 layer was to impart higher sensitivity to H_2 in the Schottky-like conduction region. The Pd/SiC diode behaved differently, exhibiting an exponential response in the low-voltage region and series-resistance effect at higher voltages. These results clearly show that the SnO_2 layer changed the basic electronic behavior and the response to H_2.

The stability and sensitivity of the sensors were also improved using the MRIS structure. Pd/SiC and Pd/SnO_2/SiC diodes were aged for several weeks at a temperature of 350 °C. In the experiments, these diodes were exposed, variously, to H_2, methane, or propylene at a concentration of 400 ppm in a carrier gas mixture of N_2 and air, at a temperature of 350 °C. During these exposures, diode currents were measured as a function of time at a fixed applied potential of 0.5 V. The results (see Figure 2) indicate that the Pd/SiC diode had been degraded during the aging process, in that this diode did not respond to H_2 in the air/N_2 carrier gas at the end of the experiment. It also did not respond to propylene or methane (not plotted in the figure). In contrast, the Pd/SnO_2/SiC diode responded to hydrogen, methane, and propylene. Thus, the SnO_2 layer made it possible to detect gases that would otherwise not be detected and enabled the desired longer-term operation of the sensor: Variation of the type of reactive insulator is expected to produce different gas sensitivities.

This work was done by Gary W. Hunter and Philip G. Neudeck of **Lewis Research Center**, *Dak Knight of Cortez III, Chung-Chium Liu and Qing-Hai Wu of Case Western Reserve University, and Liang-Yu Chen of National Research Council. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7–3, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16544

Dual-Function Microelectronic Sensors

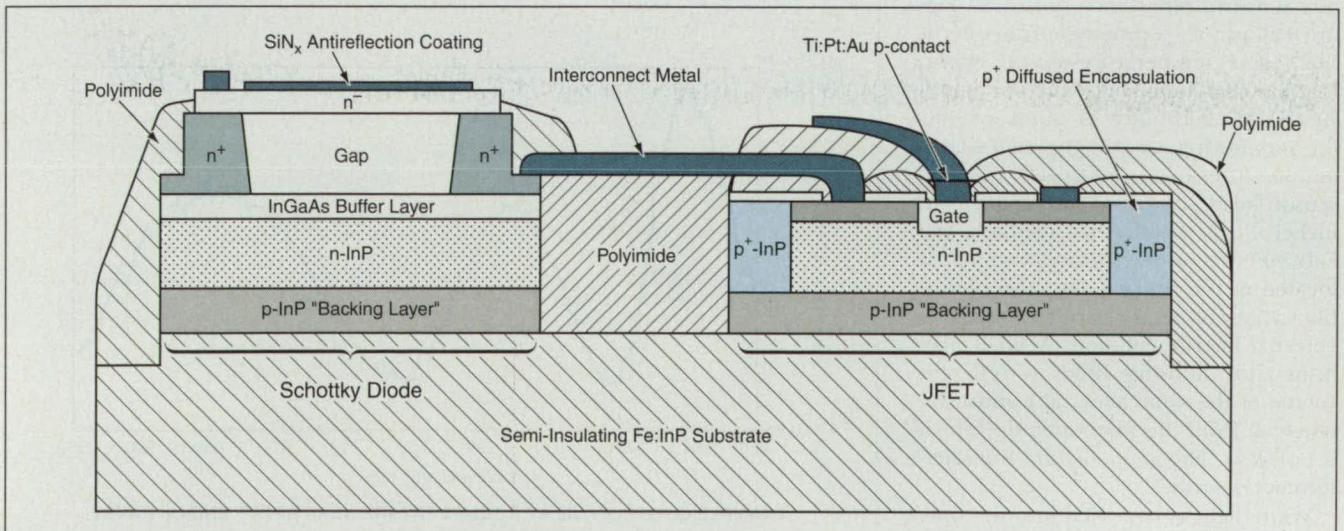
Scenes could be imaged in a visible/infrared band, an infrared band, or both.

NASA's Jet Propulsion Laboratory, Pasadena, California

Integrated-circuit image sensors of a proposed type would be capable of operation in either the wavelength band of 0.5 to 2.5 μm, the wavelength band of 2.8 to 5.8 μm, or both bands simultaneously. Called "dual function, thermal optical image sensors" (DTOISs), these sensors could be useful in a variety of scientific, industrial, and medical applications in which there are needs for visible and infrared imaging — typically, for noncontact measurements of temperature distributions. In medicine, for example, such measurements could provide early indications of developing tumors.

Each pixel of a DTOIS (see figure) would contain a "lifted," bridged InGaAs Schottky diode for sensitivity in the 2.8-to-5.8-μm band, integrated with an InP junction field-effect transistor (JFET). Also integrated with the bridged Schottky diode and JFET would be the already developed InGaAs positive/intrinsic/negative (PIN) photodiode (not shown in figure) for sensitivity in the 0.5-to-2.5-μm band. Each of these sensory devices would be connected to a dedicated active pixel readout circuit so that the image in either or both wavelength band(s) could be read out. The pixel-addressing scheme of the readout circuits would involve the use of JFETs instead of conventional multiplexers.

The planned development of the DTOISs would build on previous accomplishments in the continuing development of InGaAs active-pixel sensor arrays, each pixel of which contains an InGaAs photogate-type sensory device integrated with a low-leakage InP JFET. The planned development would also



The **Sensory Devices** in each pixel of a DTOIS would be a bridged Schottky diode (sensitive in the longer-wavelength infrared band) and a PIN-diode (sensitive in the shorter-wavelength visible/infrared bands, not shown in the figure) with JFET(s).

incorporate techniques developed previously for the fabrication of GaAs Schottky diodes for operation at frequencies from 240 to 640 GHz. Current plans for proof of the DTOIS concept call for development of a prototype DTOIS for a microbiological application. The major technical challenge will be to design a lifted Schottky diode to increase thermal sensitivity so that spatial, temporal, and thermal resolutions could be superior to those of pre-existing detectors. Inasmuch as an array of lifted Schottky diodes would supplant the silicon-resistor arrays of state-of-the-art thermal sensors, the thermal resolution of the DTOIS is expected to be finer than the value of 0.04 K claimed previously for a monolithic silicon focal-plane array. Also, because of the high charge-carrier mobility of InGaAs, the thermal response of the DTOIS is expected to be faster than that of a silicon sensor by a factor of about 6. The ability to detect photons in the 2.8-to-5.8-μm wavelength band would constitute an additional advantage over a silicon sensor.

This work was done by Quiesup Kim of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Circuits category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Refer to NPO-20430, volume and number of this NASA Tech Briefs *issue, and the page number.*

Fabry-Perot Fiber-Optic Temperature Sensor

This is a prototype of rugged sensors for use in advanced engines.

Lewis Research Center, Cleveland, Ohio

A class of developmental photonic temperature-measuring systems is based on the use of miniature, fiber-optic-coupled Fabry-Perot interferometers as temperature transducers. These systems are intended for monitoring and control of advanced aircraft engines, conventional and nuclear powerplants, industrial plants, and other systems in which conditions could be too severe for electronic temperature sensors (thermocouples, thermistors, and bimetallic devices). Unlike electronic temperature sensors, these and other photonic temperature sensors do not pose a sparking hazard and are insensitive to electromagnetic interference at suboptical frequencies.

In essence, a Fabry-Perot fiber-optic temperature sensor provides a temperature-sensitive reflectance spectrum. Figure 1 illustrates a prototype Fabry-Perot fiber-optic temperature-sensor system that has been built and tested to demonstrate the feasibility of such systems for monitoring aircraft-engine exhaust temperatures from –50 to +600 °C. The sensor head comprises an Inconel™ (a nickel-alloy) sheath that contains the Fabry-Perot interferometer, which is located at the tip of a sapphire optical fiber that connects the sensor head to external instrumentation. A small platinum-alloy housing holds a reflector (made of the same alloy) at a short distance, *d*, from the fiber-optic tip, which is polished. The gap *d* defines the interferometer cavity.

White light is launched into the optical fiber via a 2:1 fiber-optic coupler at the end opposite the sensor head. The light travels along the fiber to the sensor

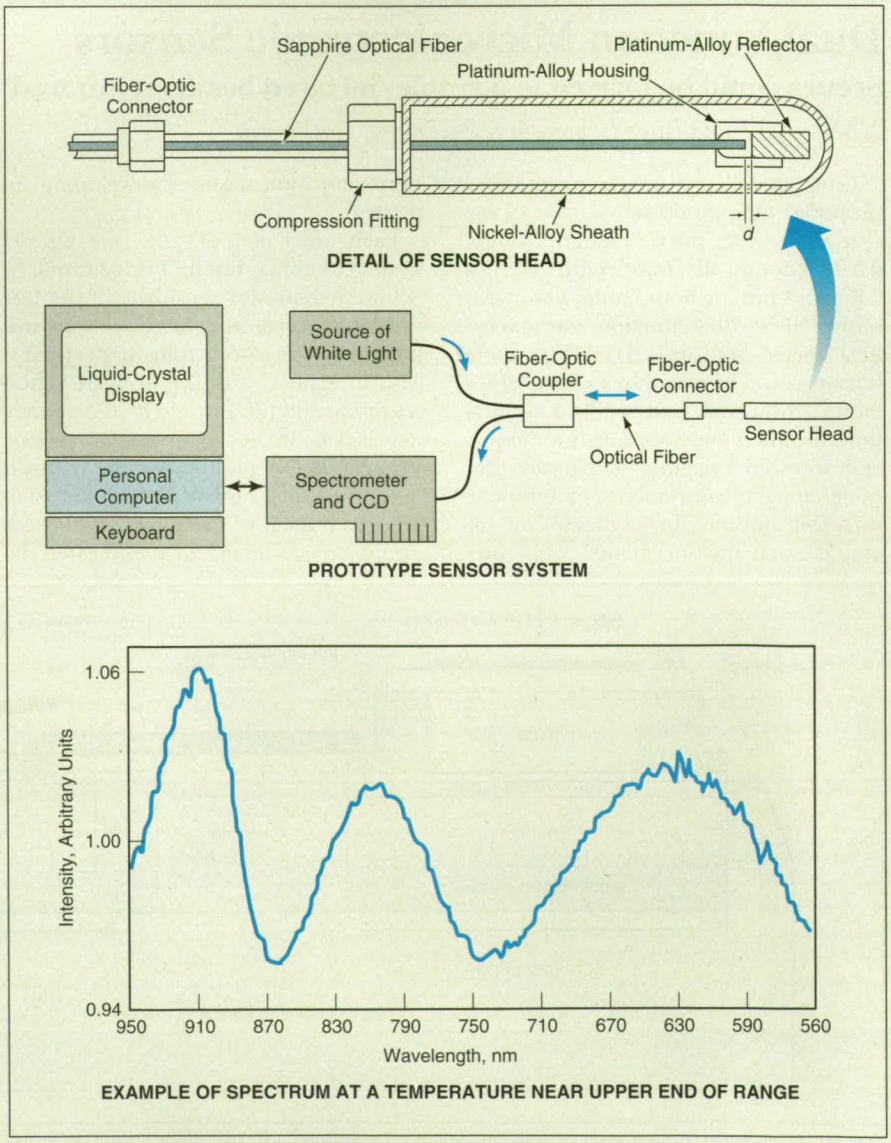

Figure 1. A **Fabry-Perot Fiber-Optic Temperature-Sensor** generates a reflected-light spectrum characteristic of the temperature in the sensor head.

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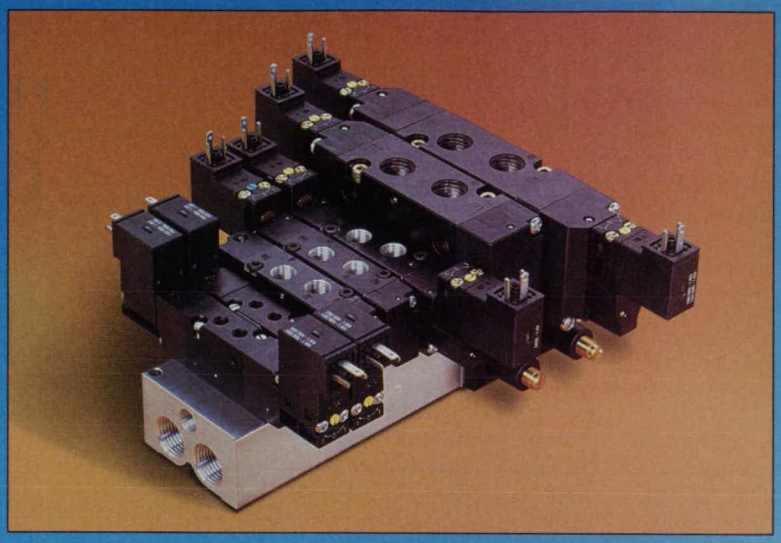

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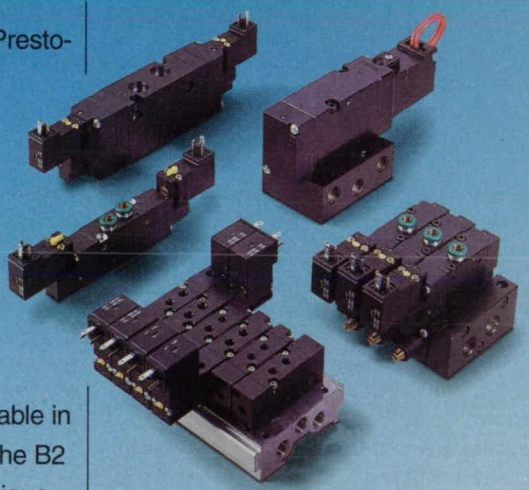

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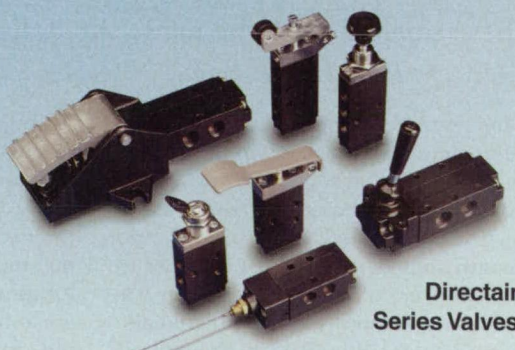

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For More Information Circle No. 542

head. About 4 percent of the incident light is reflected back along the fiber from the polished tip. The remainder of the incident light travels on to the platinum-alloy reflector, and about 90 percent of the light incident on the reflector re-enters the fiber and propagates back along the fiber, along with the light reflected from the fiber tip.

The fiber-optic coupler directs the two backward-propagating light beams to a spectrometer that is integrated with a 1,000-pixel linear charge-coupled-device (CCD) photodetector array on a computer plug-in spectrometer card. Because of interference between the two backward-propagating beams, the CCD output shows characteristic interference fringes; that is, a reflected-intensity-vs.-wavelength spectrum. Because of the difference between the coefficients of thermal expansion of the sapphire optical fiber and platinum-alloy housing and reflector, d varies with temperature, giving rise to a change in the spectrum. Among other things, the number of interference fringes in this spectrum increases with temperature.

The raw reflectance spectrum is divided by the spectrum of the incident white light to obtain a normalized spectrum. The computer calculates the squared difference between the normalized spectrum and each of 117 stored calibration curves, which are normalized spectra that correspond to known temperatures at 5 °C increments. A parabolic interpolation is used for temperatures between the increments. The measured temperature is taken to be the temperature that yields the minimum squared difference.

In an experiment, the prototype Fabry-Perot fiber-optic temperature-sensor system was used, along with a thermocouple, to monitor the exhaust temperature of an aircraft engine. The Fabry-Perot temperature readings agreed closely with the thermocouple readings (see Figure 2). In more than 50 hours of flight tests, the prototype system proved to be immune to source fluctuations and to deterioration of optical surfaces inside the sensor head. The prototype system functioned under normal flight conditions and during severe maneuvers with accelerations as large as 4 times the normal Earth gravitational acceleration.

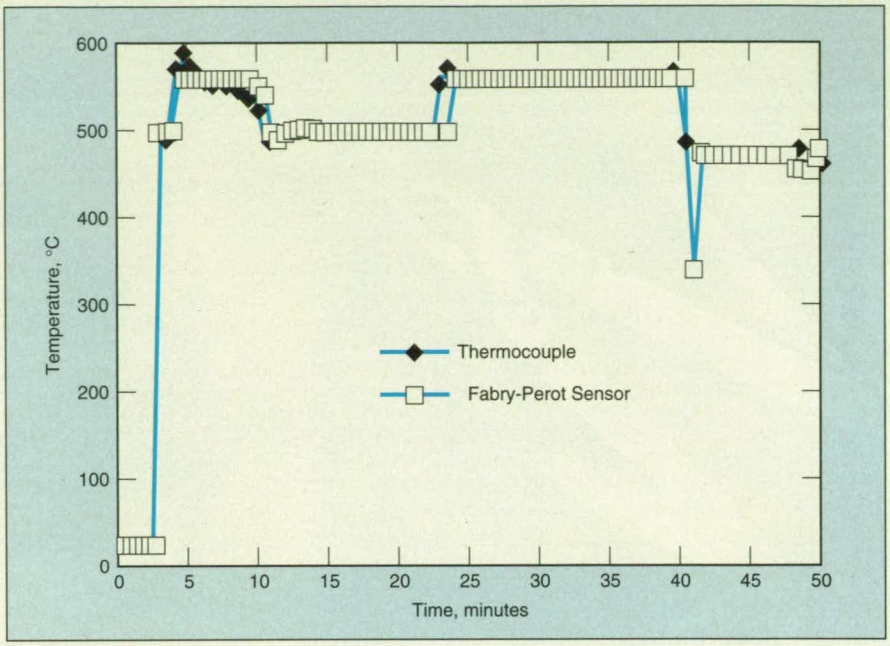


Figure 2. The **Temperatures in These Plots** were calculated from measurements taken during straight and level flight. The two sets of temperatures from measurements taken during severe maneuvers agreed almost as well.

This work was done by Takeo Sawatari, Yuping Lin, and Phil Gaubis of Sentec Corp. for **Lewis Research Center**. *Sensor calibration and flight tests were conducted by Margaret L. Tuma of* **Lewis Research Center** *and Kristie A. Elam of Gilcrest Electric Co. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

Takeo Sawatari
Sentec Corporation
2000 Oakley Park Road, Suite 205
Walled Lake, MI 48390

Refer to LEW-16610, volume and number of this NASA Tech Briefs *issue, and the page number.*

Integrated Electrochemical Sulfur Dioxide Sensors

These sensors could be made small, lightweight, robust, and portable.

NASA's Jet Propulsion Laboratory, Pasadena, California

Integrated electrochemical sensors are being developed for use in measuring concentrations of sulfur dioxide in gas mixtures. These sensors are based on the electrochemical oxidation of SO_2 and measurement of the resulting electric current. Conceived for sensing SO_2 in volcanic gases, sensors of this type could also be used to monitor SO_2 in ambient air and in gases emitted during such industrial operations as metallurgical processing, refining of petroleum, and burning of coal.

Concentrations of SO_2 can be measured by mass spectrometers, but these instruments are too power hungry, heavy, and bulky to be portable, and their response times are too long for taking repetitive measurements in unsafe locations. The developmental sensors are inherently simple and fast-responding and could be made small, lightweight, and robust for incorporation into portable instruments that could be operated in industrial and remote natural settings.

A sensor of this type includes an integrated catalytic-electrode/ion-conducting-membrane/catalytic-electrode sandwich structure (see figure). The membrane is made of a proton-conducting polymer (for example, Nafion 117 or equivalent). The catalytic electrodes are made of porous carbon (graphite-based) paper substrates coated with catalysts in the form of platinum or platinum alloy powders. The electrodes on opposite sides of the membrane can be identical or different with respect to cat-

alysts and treatments of the porous substrates. Such electrode/membrane/electrode sandwiches and techniques for fabricating them have been described in a number of previous articles in *NASA Tech Briefs*.

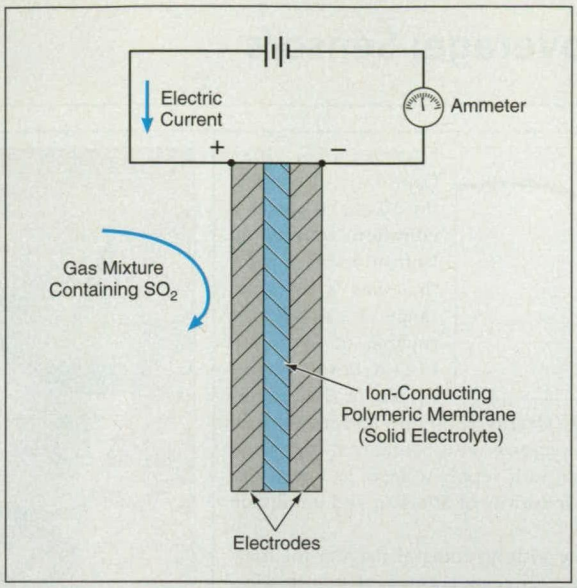
In operation, a dc potential is applied between the electrodes while the positive electrode is exposed to a gas mixture that contains SO_2. At the positive electrode, SO_2 in the presence of H_2O is oxidized to sulfate ions, with production of hydrogen ions, in the following chemical reaction:

$$SO_2 + 2H_2O \rightarrow SO_4^{2-} + 4H^+ + 2e^-$$

The hydrogen ions are conducted through the membrane to the negative electrode. Upon arrival at the negative electrode, the hydrogen ions react as follows:

$$2H^+ + 2e^- \rightarrow H_2$$

The current of hydrogen ions through the membrane gives rise to a measurable electric current in the wires connecting the electrodes to the source of applied potential. For a given fixed applied potential, the current is expected to be proportional to the concentration of SO_2 in the gas in contact with the positive electrode.

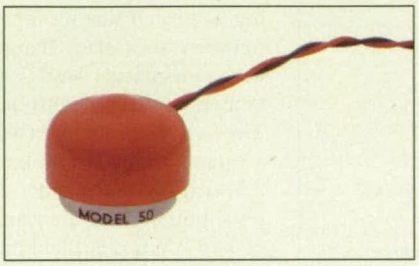


The **Current in This Electrochemical Sensor** is expected to be proportional to the concentration of SO_2 in the gas to which the positive electrode is exposed.

The use of noble-metal catalysts and graphite-based substrates makes the electrodes resistant to chemical degradation. The Nafion 117 or equivalent membrane material is a sulfonic acid-based polymer that also resists chemical degradation.

An experimental sensor was made from a conditioned Nafion membrane and electrodes comprising porous carbon paper catalyzed with platinum black. The electrodes were bonded to the membrane. The resulting sandwich was mounted between two glass flanges with electrical leads attached to the electrodes. The active sensor area was a square about 1 in. (about 2.5 cm) on each side. In tests, potential in the range of 1 to 2 V was applied and currents were measured with and without exposure to SO_2. Current responses on exposure to SO_2 were significant, and the response time was about 1 s. Further studies to quantify responses and sensitivity to operating variables were under way at the time of reporting the information for this article.

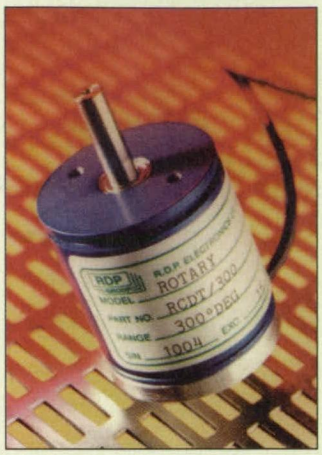
This work was done by Sekharipuram Narayanan and Santosh Srivastava of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category. NPO-20290*



Endevco, San Juan Capistrano, CA, offers the Model 50 **portable vibration sensor**, an Isotron accelerometer that has a dynamic range of ±40 g and is capable of operating from a 12-volt battery supply or wall transformer. It measures 0.285 × 0.5", weighs 3.8 grams, and includes an integral amplifier. The built-in microcircuit is configured to work in a constant current mode for use with supply voltages as low as +12 Vdc. The sensor offers voltage sensitivity of 50mV/g and amplitude response of one to 5,000 Hz.

The accelerometer is available with an integral magnet for magnetic mounting. It comes with a three-meter pair of output wires attached. A matching 10-channel power supply also is available. The inside of the protective vinyl on the sensor can be filled with RTV for resistance to moisture at the connection junctions.

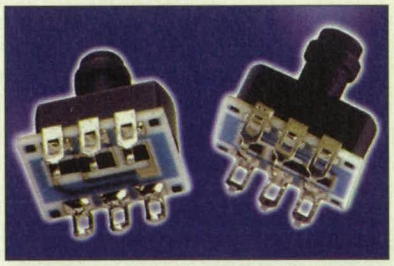
For More Information Circle No. 700



RDP Electrosense, Pottstown, PA, offers the RCDT 300 capacitive **rotary displacement sensor** that provides a 300° linear range, and is accurate to 1% F.S. The transducer measures the angular position of its shaft, with respect to its body. The sensor includes hybrid electronic circuitry, operates from a 13-18Vdc supply, and has a 3-volt full-scale output. The sensor is designed for applications such as machine tool installations, industrial automation, robotics, and test stands.

The rotary position of an eccentric shaft is measured using a non-contact position measurement technique that maintains the quality of the data. A precision bearing set maintains the unit's resistance to off-axis forces.

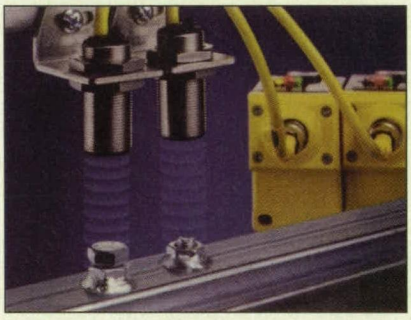
For More Information Circle No. 701



The InCap™ **barometric pressure sensor** from Kavlico Corp., Moorpark, CA, utilizes the company's patented Integrated Capacitive technology. The silicon micromachined design combines the electronics and sensor onto a single chip. Each sensor is amplified, trimmed, and temperature-compensated from -40°C to +125°C, with a storage temperature range from -50°C to +150°C. Total error band (trim tolerance, linearity, hysteresis, and repeatability) over -10°C to +85°C is ±1.5% of full scale.

The sensor features shock and vibration resistance, offers a maximum response time of 10 ms, requires no warm-up, and can be used with remote battery operation. The sensor is designed for high-volume applications and can be configured with 6 "J" pins for surface mounting, or with straight pins for PC board mounting.

For More Information Circle No. 703



The U-GAGE™ Q45UR **ultrasonic sensors** from Banner Engineering Corp., Minneapolis, MN, are available in switched output (discrete) and analog models, both with a remote sensing head to access applications with limited space, or difficult environments. They utilize pushbutton programming, allowing users to set their own custom sensing windows. Discrete model sensors can be programmed for on/off presence detection.

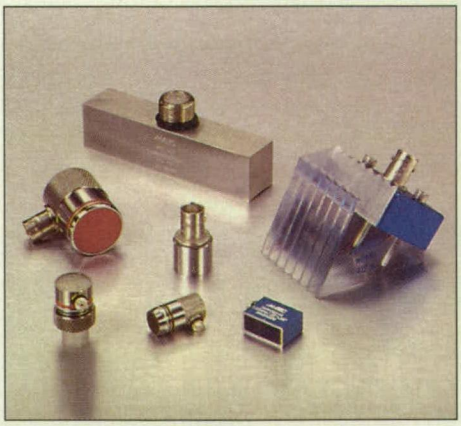
Analog sensors feature 0.080 mm to 0.228 mm resolution, with a sensing range of 50 to 150 mm. They feature selectable response modes and speeds, and their output can be set to a positive or negative slope. Output response speed is set using the single-turn potentiometer.

For More Information Circle No. 706

Superprox® Model SM906 Series **ultrasonic sensors** are available from Hyde Park Electronics, Dayton, OH, for analog sensing applications. The sensors monitor the distance to an object while generating a proportional analog output relative to two span limits, which can be easily set with the push of a button. Packaged in a 30-mm threaded, barrel-style, ULTEM blue plastic or stainless steel housing, the sensors can be installed in vessel covers or other hard-to-mount areas.

Features include 0 to 10 Vdc or 4 to 20 mA output either directly or inversely proportional; a range of one or two meters; five different response times from 15 ms for the one-meter range and 20 ms for the two-meter range, to 2.5 seconds for either range; and a choice of output states for loss of echo and power-up.

For More Information Circle No. 707



ValpeyFisher, Ultrasound and Optics Division, Hopkinton, MA, offers a line of **ultrasonic transducers** for the detection of material flaws, material thickness, and materials research and medical diagnostic applications.

Product types include contact, immersion, angle beam, delay line, and high-frequency transducers. The ultrasonic sensors are available in stock models, or can be customized to meet specific applications.

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High-Efficiency, Long-Life Pulsed Inductive Plasma Thrusters

Advanced pulse circuits deliver optimally shaped pulses and recover reflected energy.

Lewis Research Center, Cleveland, Ohio

Improved pulsed inductive plasma accelerators are undergoing development for use as long-life thrusters for propulsion of spacecraft on interplanetary missions and for maneuvering of spacecraft in orbit around the Earth. On Earth, plasma accelerators of this type could be used to produce a variety of atomic, molecular, and plasma beams for scientific experimentation and industrial processing (especially processing of materials in the fabrication of microcircuits). The principal advantages of the developmental accelerators over older pulsed inductive plasma accelerators arise from the use of advanced solid-state electronic pulse circuits, which operate at high repetition rates (as much as a couple of kilohertz), have long operating lives (10^{11} shots), deliver optimally shaped pulses, and recover reflected energy.

Some discussion of pulsed inductive plasma accelerators in general is prerequisite to a meaningful description of the present improved design concept. Figure 1 illustrates the basic principle of operation. A short pulse of electric current is sent through the coil by closing an electronic switch between a coil and a previously charged capacitor bank. The rapid rise of the axial magnetic field produces an azimuthal electric field, which electrically breaks down a propellant gas in a chamber adjacent to the coil, creating a plasma current ring in the direction opposite that of the current in the coil. The magnetic repulsion between the currents in the coil and the plasma drives the plasma away from the coil.

Pulsed inductive plasma accelerators offer advantages over electric plasma accelerators, in which electrodes supply currents to form the plasmas. Erosion of electrodes severely limits operational lifetimes and introduces electrode atoms into the plasmas. In the case of a plasma for industrial processing or scientific experimentation, contamination with electrode material can

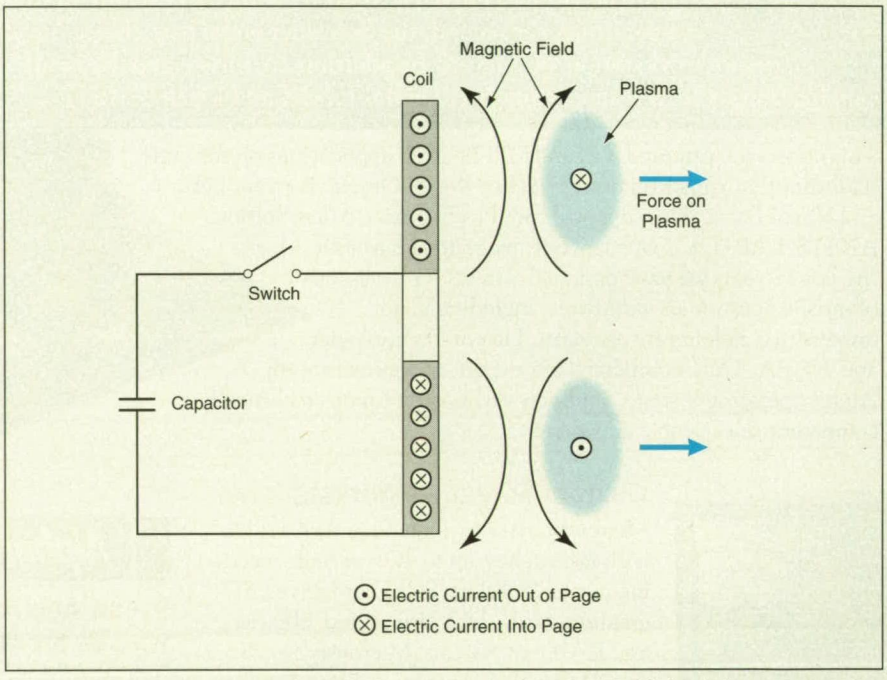

Figure 1. The **Pulsed Current in the Coil** generates a pulsed magnetic field that induces an opposing current in the plasma, with resultant magnetic force that pushes the plasma away from the coil.

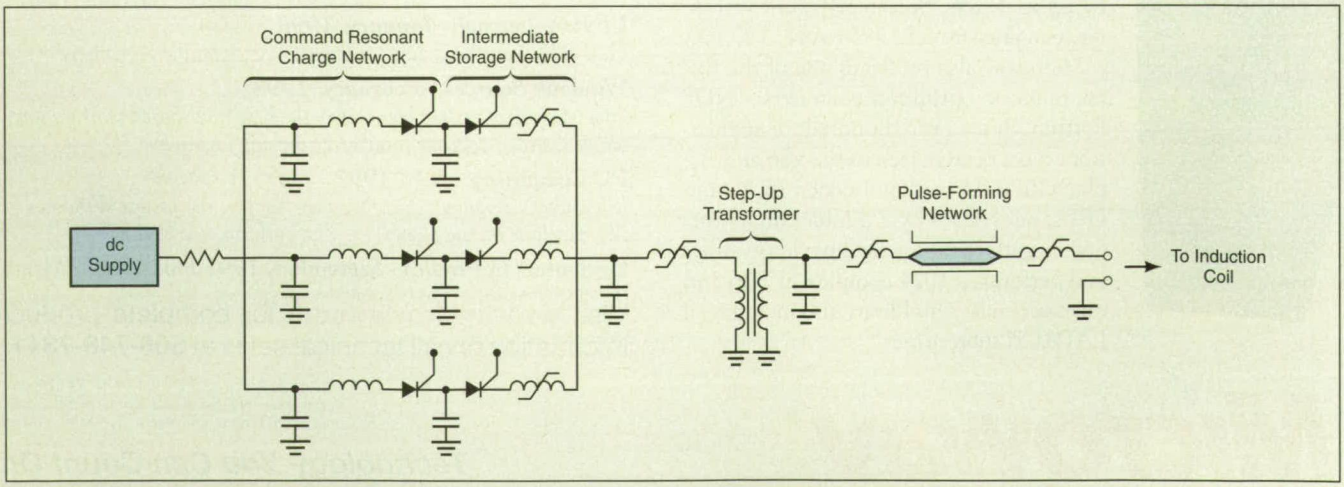

Figure 2. This **Pulsed Driver Circuit** converts dc input power to short, high-voltage pulses. For example, with a suitable choice of components, it can covert 500-Vdc input to 50-kV, submicrosecond pulses. A pulsed driver circuit for a specific application could differ in such details as the numbers, ratings, and placements of capacitors, inductors, and SCRs.

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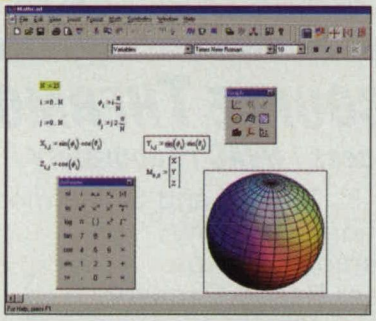

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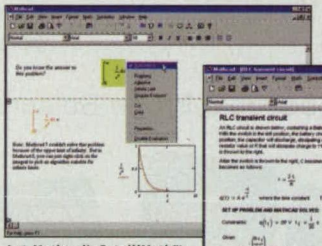

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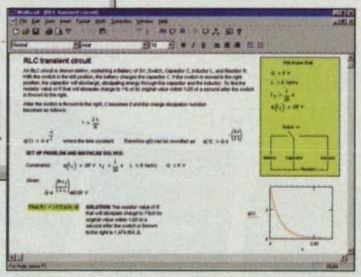

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be unacceptable. Because a pulsed inductive plasma accelerator operates without electrodes and the plasma is pushed away out of contact with the induction coil immediately upon formation, there is much less erosion, and the plasma is much cleaner than in an electric plasma accelerator.

Until now, the performances of pulsed inductive plasma accelerators have been constrained by the unavailability of reliable, long-life, efficient pulse-power circuits. The gas spark-gap switches used in older pulsed inductive plasma accelerators are unreliable and short-lived (a few million shots maximum) because of erosion of spark-gap electrodes and contamination of gases. With regard to efficiency, two major issues arise:

- The pulse delivered by the power circuit in a typical older pulsed inductive plasma accelerator is not shaped to maximize energy efficiency. Before breakdown, the self-inductance of the coil limits the initial current rise; after breakdown the magnetic flux of the plasma current opposes that of the coil, so that the net inductance is reduced and the current rises rapidly. However, what is needed for efficient operation is a rapid initial current rise to obtain a strong electric field for uniform breakdown, followed by a slower current rise during acceleration to reduce resistive loss of energy in the plasma.
- Because of variation of the load impedance with acceleration of the plasma, some (typically 20 to 25 percent) of the energy fed to the accelerator is reflected. If the reflected energy can be recovered, then efficiency can be increased. The pulse-power circuits of older pulsed inductive plasma accelerators are not designed to recover the reflected energy.

In the developmental pulsed inductive plasma accelerators, the issues of optimal pulse shaping, recovery of reflected energy, and reliability of the switches are all addressed in the design of advanced pulsed driver circuits. These are compact, lightweight, modular solid-state circuits that contain (1) inductive and capacitive elements for storing energy and shaping pulses and (2) silicon controlled rectifiers (SCRs) for switching. Figure 2 shows a simplified version of a circuit of this type to illustrate the principle of operation. The input stage of the circuit is a command resonant charge (CRC) network controlled via SCRs. The CRC network delivers a preset quantity of charge and energy to intermediate storage capacitors between pulses. The pulses formed by the CRC

are then compressed by a nonlinear inductance-and-capacitance network that includes a step-up transformer to obtain desired impedance levels.

The nonlinear circuit elements are inductors with saturable cores. The core of each following stage is allowed to saturate before a significant fraction of energy stored in the capacitors of the immediately preceding stage is transferred. The nonlinear saturation phenomenon increases the resonant frequency. Thus, energy is coupled progressively faster as it propagates through successive stages from the input to the output end. The circuit is efficient in transferring power in both directions because it not only upshifts frequency in the forward direction as described above but also downshifts frequency as a reflected pulse propagates back toward the input end. Energy reflected from a mismatched load can propagate all the way back to the SCR commutator. There, an energy-recovery circuit (omitted for clarity) that comprises inductors, capacitors, and SCRs stores some of the reflected energy, which is then added to the forward-propagating energy on the next pulse.

This work was done by Dennis A. Rally, Xing Chen, and William Guss of Science Research Laboratory, Inc., for **Lewis Research Center.** *For further information, access the Technical Support Package (TSP)* ***free online at www.nasatech.com*** *under the Electronic Components and Circuits category*

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Solar-Cell System With High Conversion Efficiency

Sunlight is spectrally dispersed to multiple cells, each responsive to part of the spectrum.

NASA's Jet Propulsion Laboratory, Pasadena, California

A concept for obtaining high energy-conversion efficiency in a solar photovoltaic system involves (1) concentration and spectral dispersion of sunlight and (2) use of several types of solar photovoltaic cells, each placed at its optimum location in the spectrum. The spectral dispersion and concentration of sunlight can be effected by use of mirrors or lenses combined with prisms. The photovoltaic cells can be of the conventional single-junction type, which cost less than do the more advanced multijunction cells.

Preliminary experiments to demonstrate the feasibility of this concept were performed on several types of cells, using artificial sunlight and prisms that had not been optimized. On the basis of these experiments plus references to the literature, it has been estimated that an opti-

Cell Type	Spectral Region of Maximum Response	Measured Efficiency, Percent (1)	Percent Contribution to System Efficiency, Calculated for Optimized Optics
Ge	Near Infrared		9.17 (2)
Si	Red or Near Infrared	7.53	12.05
GaAs	Orange and Red	9.99	15.98
$GaInP_2$	Green and Yellow	5.57	8.91
GaN or GaP	Ultraviolet and Blue		2.73 (2)
Projected System Efficiency			48.84

Footnotes:
(1) At a concentration of 7 Suns measured at a prism lens.
(2) Estimated from the literature, without correction for concentration.

Each Type of Photovoltaic Cell responds maximally in a unique part of the spectrum, thereby contributing to overall efficiency in the conversion of spectrally dispersed sunlight to electricity.

mized system of this type could perform with an energy-conversion efficiency approaching 50 percent (see table). In contrast, the more-expensive multijunction solar cells yield efficiencies between 20 and 30 percent, while the efficiencies of conventional solar cells range from 11 to 19 percent in white light.

This work was done by Wayne Phillips of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Circuits category*
NPO-20354

Luneberg Lenses Made of Open-Cell Polyurethane Foams

Advantages would include light weight and ease of fabrication.

NASA's Jet Propulsion Laboratory, Pasadena, California

A Luneberg lens is a microwave lens consisting of a series of concentric shells of differing dielectric constants. The highest dielectric constant, or refractive index, resides at the core, and the lowest at the outer shell. Microwaves passing through this arrangement of shells are focused in the same manner as light passing through a glass lens.

Known for decades, Luneberg lenses have been fabricated from materials such as polystyrene foam, foamed glass, and other cellular materials. The dielectric constant is controlled by simply controlling the bulk density of the foam. Materials, such as foamed polystyrene, are useful for ground-based applications, but space deployment imposes severe restrictions on their use. The closed-cell materials used in the past are frequently difficult to fabricate and are high in mass and tend to exhibit electrical and dimensional instabilities. They may also be expensive and vulnerable to fracture by ground handling or launch vibrations.

This concept proposes Luneberg lenses suitable for space applications and fabricated from open-celled elastomeric foams. An ideal candidate is the class of foamed urethane polymers. The dielectric constant of these materials is controlled by varying the density of the foam, but may also be varied by addition of polar groups (*e.g.*, ethoxy, sulfonyl, carboxylate, trifluoropropoxy, and the like) to the polymer backbone. Unlike increasing the dielectric constant by the addition of conductive compounds, this approach maintains the electrons in the valence band and consequently keeps the loss tangent low.

Urethane is the most widely used chemistry in the fabrication of open-celled foam materials, with densities ranging from 1.2 to 10 lb/ft^3 (19.2 to 160 kg/m^3). Dielectric constants typically vary from 1.05 to 4.0 at high densities, and loss tangents vary from immeasurably small to 5×10^{-3}. Both mechanical and dielectric properties are identical in all axes (isotropic), solving a significant problem with previous materials choices. These open-celled foams are inexpensive, easy to machine and low in density. Their open cell structure results in rapid and complete air release in the vacuum of space. The inherent resilience of these materials gives them high mechanical damping, resistance to fracture during handling and launch, and additionally provides a positive restoring force to their dimensions. This "self-correcting" property overcomes the "airgap" problem of previous designs, in which a slight separation between the shells results in an internal reflection and loss of RF (radio-frequency) efficiency. Finally, these materials have extremely low thermal conductivity (typically 0.05 W/m-K). This last characteristic prevents the lens structure from undergoing dramatic temperature swings in response to a changing thermal environment, and further improves their electrical stability. Luneberg lenses fabricated from these inexpensive open-celled urethane foams may additionally be supported for use by a thin-walled lightweight shell of some other material, such as fiber glass.

This work was done by Paul B. Willis of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Circuits category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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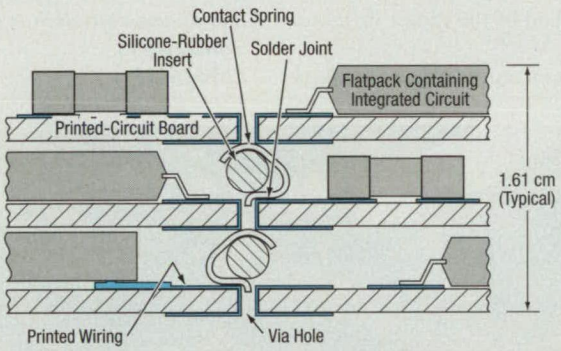
Refer to NPO-20339, volume and number of this NASA Tech Briefs *issue, and the page number.*

Packaging Electronic Circuits in Multi-Board Modules

Neither cables nor traditional connectors are used within modules.

NASA's Jet Propulsion Laboratory, Pasadena, California

The Multi-Board Module (MBM) scheme has been conceived to provide a cost-effective way to combine digital electronic circuits into dense, lightweight packages, within which high-speed signals can be transmitted readily along three-dimensional conductive paths with minimal lengths. As the title suggests, the MBM scheme involves stacking of circuit boards in modules. Unlike in other circuit-packaging schemes, neither cables nor traditional electrical connectors are used to make the electrical connections among circuit boards in a module. Inasmuch as connectors and cables typically occupy a large fraction of the volume and constitute a large fraction of the mass of a package, the MBM scheme offers the potential for significant reductions in size and weight.



Contact Springs made of beryllium/copper provide electrical connections between printed-wiring traces on adjacent circuit boards stacked in a module.

As shown in the figure, the connections between two adjacent circuit boards are made via gold-plated beryllium/copper contact springs. Each contact spring is soldered to printed wiring at a via hole on one of the boards. During assembly, each spring is pushed into contact with the printed wiring at a via hole at the corresponding location on the adjacent board. Inserts made of silicone rubber can be used to reinforce the contact springs.

In addition to eliminating the cost, weight, and bulk of cables and traditional electrical connectors, this contact scheme affords several advantages:

- The contacts are self-aligning and structurally reliable.
- Maintenance, repair, and testing are possible because circuit boards can readily be removed from stacks.
- To facilitate testing, one can turn off selected contacts by inserting insulating tabs; alternatively or in addition, one can insert thin conductive pads at selected contacts to gain access for probing.
- Unlike in conventional edge connection and in other three-dimensional-connection schemes, contacts can be located almost anywhere on the circuit boards; this makes it possible to reduce signal-path lengths and thereby accommodate higher-speed signals.

In applying the MBM concept, designers might have to contend with limits on the sizes of modules and with guidelines regarding the numbers and placements of contacts and structural supports. High circuit densities could give rise to a need for thermal straps for additional heat sinking. Under some circumstances, it could be necessary to design against a tendency for contacts to open when the circuit boards are subjected to strong vibrations.

This work was done by John D. Baker and Alberto Montalvo of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Circuits category.*

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Program Simulates Performance of a Hybrid Automobile

The Hybrid Electric Vehicle Analysis (HEVA) computer program numerically simulates the performance of an automotive vehicle — especially a hybrid vehicle. A vehicle is said to be hybrid if (1) it contains an energy-storage device (a battery, flywheel, or ultra-capacitor) that is charged with energy from a heat engine that burns natural gas or another fuel and (2) the energy-storage device is part of a system that provides electricity to a traction motor for propulsion.

HEVA can mathematically model the performance of a conventional nonhybrid vehicle, which lacks an energy-storage device. It also accounts for energy recovered by regenerative brakes. For a given vehicle design and given operating conditions, HEVA calculates fuel economy and estimates itemized power flow, wheel and motor moments, and behavior of the energy-storage system. The algorithms in HEVA incorporate the assumption that the only direct source of motive power is an electric motor. HEVA cannot be used to analyze a hybrid vehicle with a parallel configuration, in which either an electric motor or a fuel-burning engine can propel the vehicle.

HEVA comprises a simulation subprogram and nine file-editor subprograms, which are used to modify the various input files. Each file-editor subprogram is dedicated to one of nine types of input files. The input data fall into the following categories:

- Operating conditions (velocity profile, road inclination, and environmental conditions);
- Some general vehicle parameters (including weight and aerodynamic characteristics);
- Engine parameters (including efficiency, power ratings, and fuel characteristics);
- Drive-train efficiency as a function of speed ratio;
- Torque supplied by the motor vs. motor speed ratio;
- Auxiliary power unit (APU) control parameters (adjusted APU power output vs. state of charge);
- Battery characteristics (open-circuit voltage and resistance vs. state of charge, rated voltage, and charge capacity in ampere-hours);
- Flywheel characteristics; and
- Capacitor characteristics (capacitance, efficiency, and maximum voltage).

HEVA is written in C++ for IBM-PC-compatible computers running Windows 95/NT. Executable code is provided. IBM Visual Age C++ is necessary for compiling any modifications of the code. The standard distribution medium for HEVA is a set of two 3.5-in. (8.89-mm), 1.44MB MS-DOS-format diskettes. An electronic copy of the documentation in HTML format is included on the distribution medium.

This program was written by D. K. Stalnaker and L. Viterna of **Lewis Research Center.** *For further information, access the Technical Support Package (TSP)* ***free online at www.nasatech.com*** *under the Software category.*

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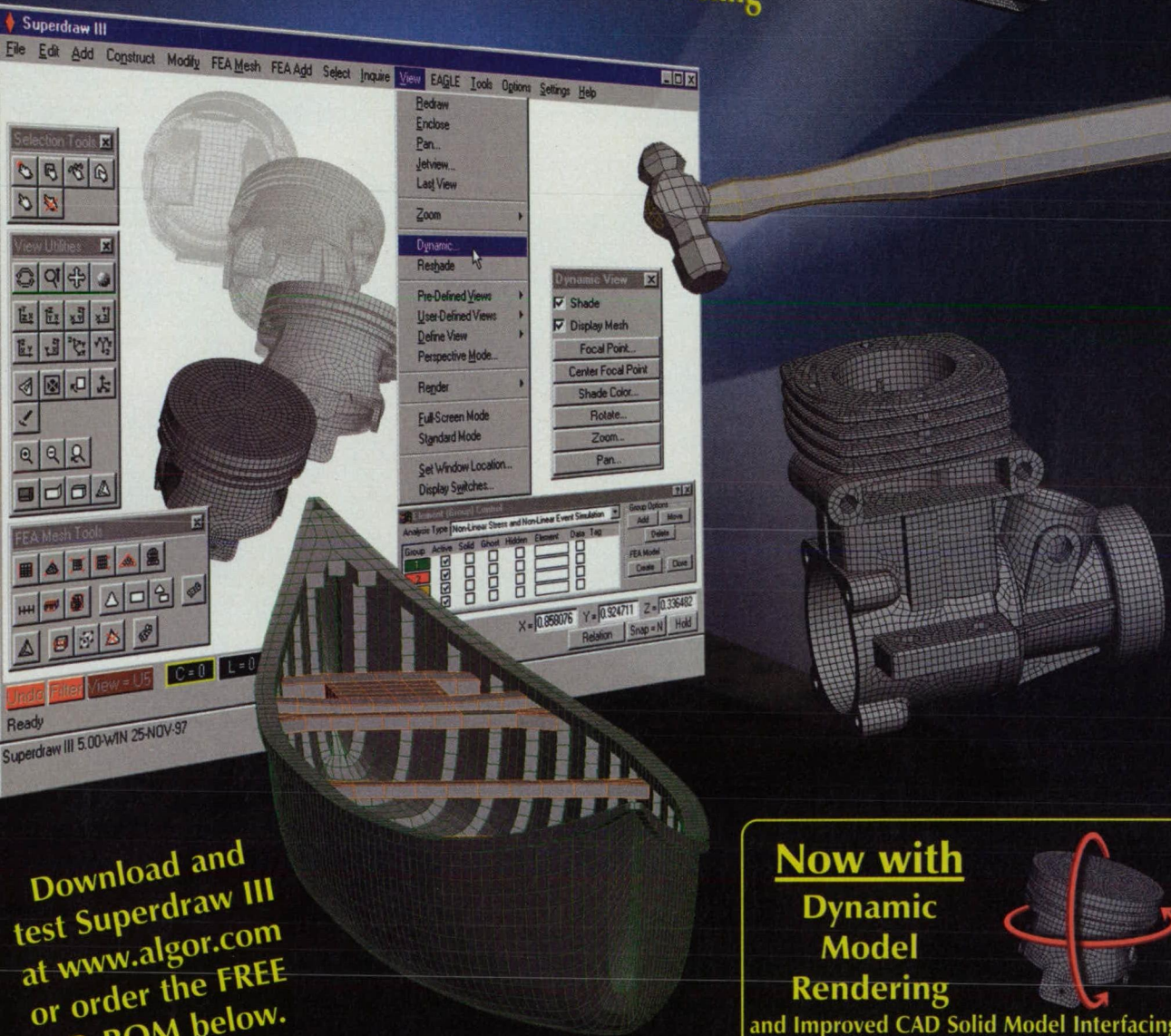

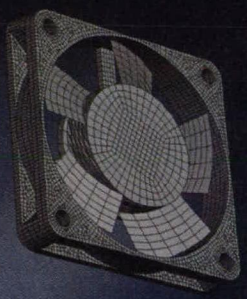

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Composite-Matrix Regenerators for Stirling Engines

One can exploit the properties of composites to reduce thermal and flow losses.

Lewis Research Center, Cleveland, Ohio

A prototype Stirling-engine regenerator containing a matrix made of carbon-fiber-based composite materials has been developed. The concept underlying this development effort is one of exploiting the properties of composite materials (e.g., the anisotropy of thermal conductivity of carbon fibers and the tailorability of composite materials and structures) to reduce thermal and flow losses below those of previously developed regenerators containing metal matrices.

The regenerator in a Stirling engine is an internal heat exchanger for transferring heat between a working fluid and a flow-channel wall (which is also part of the regenerator). The fluid can be helium or another gas that has suitable thermodynamic properties and that does not react chemically with engine components. A typical regenerator is cylindrical in overall shape and includes one or more axial passage(s) containing a matrix — an open, thermally conductive structure with many flow paths and large surface area for transfer of heat to and from the working fluid. ("Matrix" as used here is meant to be distinguished from "matrix" as used elsewhere to designate the nonfibrous or nonparticulate component of a composite material. Hereafter in this article, the terms "regenerator matrix" and "matrix material" will be used to avoid ambiguity.) Stated somewhat differently, the matrix provides a thermal connection between the gas and the heat capacity of the wall.

Problems associated with making effective regenerators stem from limitations of materials of which they are made. Regenerator matrices are subjected to hot, oscillating gas flows and high temperature gradients. For high performance, a regenerator should be thermally insulating in the axial direction (along which a substantial thermal gradient can exist) and should exchange heat rapidly with the working fluid. The regenerator should contain minimum dead volume because dead volume reduces the engine compression ratio. The flow of gas through the regenerator matrix introduces drag and viscous losses, which should be minimized in order to maximize performance. Efforts at reducing some loss mechanisms tend to aggravate others.

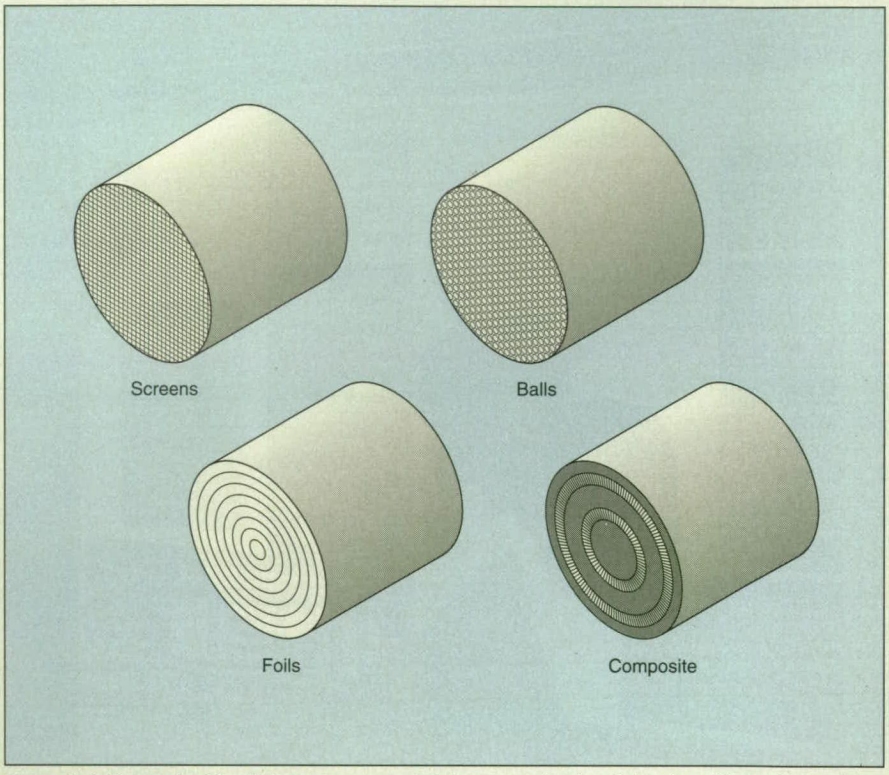


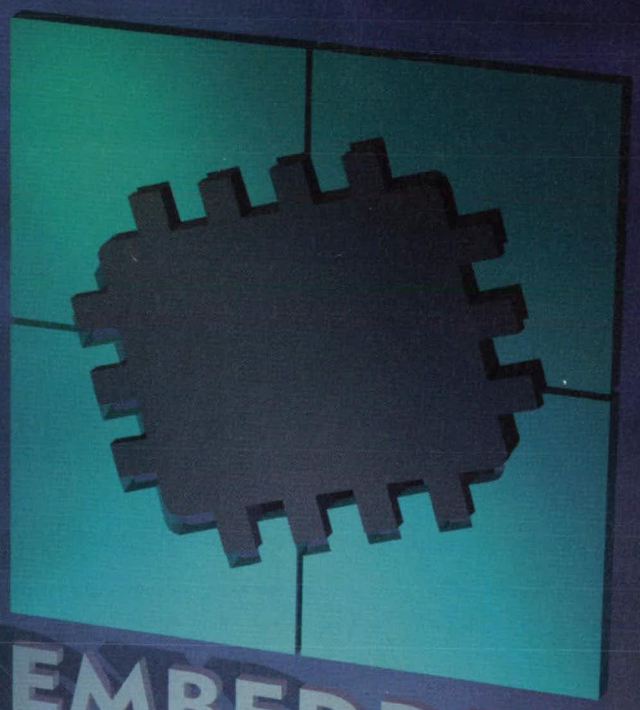
Figure 1. A **Composite-Matrix Regenerator** containing a matrix of radial carbon fibers offers advantages over current regenerators containing matrices of screens, balls, or foils.

Matrices in current regenerators have been made of various components, including steel wool, steel felt, stacked screens, packed balls, metal foils, and parallel plates. The matrix in a composite-matrix regenerator (CMR) could be made in any of a variety of composite materials and configurations; for example, regenerator matrices could comprise radially or circumferentially oriented thick fibers (see Figure 1). The fibers in the channels could be composites built up on thinner carbon-based fibers. The ends of the fibers would be embedded in cylindrical or otherwise-shaped axial-flow-channel walls.

Relative to current regenerators containing packed balls, felts, or stacked screens, CMRs containing fibers across axial-flow channels offer the potential advantage of greater heat-transfer effectiveness for a given flow friction. The high surface area of the fibers enhances gas/solid heat transfer, making it possible to obtain adequate performance from fewer, wider flow channels than one might otherwise need; this creates an opportunity to reduce costs because fewer, larger channels can be fabricated more easily. Other advantages of CMRs containing fibers crossing axial-flow channels, relative to current regenerators, include smaller pressure drops and smaller dead volumes.

The lengthwise thermal conductivities of graphitized carbon fibers range from about 300 to about 1,000 $Wm^{-1}K^{-1}$ — about 20 to 67 times the thermal conductivity of stainless steel. The transverse thermal conductivities of these fibers are only about 1/100 of their lengthwise conductivities. If these fibers were combined with low-thermal-conductivity matrix materials, the resulting composite materials would exhibit high anisotropy

Embedded knowledge in focus.



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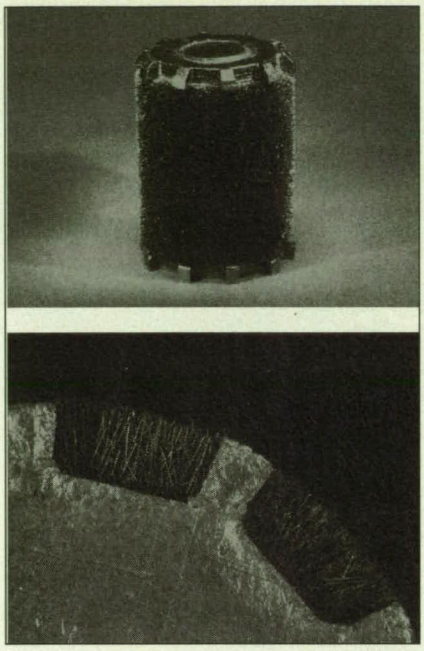

Figure 2. This **Prototype Composite-Matrix Regenerator** is made of radially oriented carbon fibers bonded to an anisotropic carbon/carbon composite tube. Fabrication involved electrostatic flocking of the carbon fibers followed by rigidization (including thickening of the fibers) by chemical-vapor infiltration.

of thermal conduction. In principle, such fibers and matrix materials could be used to advantage in a regenerator in the following ways:

- The fibers could be used to conduct heat between the flowing gas and the flow-channel walls.
- The walls could be made of a composite material containing radially oriented fibers to utilize the thermal-conduction anisotropy to maximize radial conduction between the wall and the fibers in the channel while minimizing undesired axial conduction. Preferably, the matrix material in the wall would be one of high specific heat as well as low thermal conductivity.

Figure 2 shows a prototype CMR. A CMR of this type has survived limited endurance testing in a small Stirling engine, where it exhibited thermal performance among the best of a number of different regenerators that were tested.

This work was done by Timothy R. Knowles of Energy Science Laboratories, Inc., for **Lewis Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7–3, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16581.

Improved Alloy for Fabrication of Combustion Chambers by VPS

A shell has been fabricated by VPS, and experiments continue.

Marshall Space Flight Center, Alabama

An alloy of 88Cu/8Cr/4Nb (numbers indicate atomic percentages) has been proposed for use in fabricating rocket-engine combustion chambers by vacuum plasma spraying (VPS). Relative to other techniques that could be used to fabricate rocket-engine combustion chambers, VPS is inexpensive. In VPS, a powder feedstock of the desired alloy becomes melted and deposited at high speed onto a substrate. Heretofore, those rocket-engine combustion chambers that have been fabricated by VPS have typically been made of the copper-based alloy NARloy-Z.

The 88Cu/8Cr/4Nb alloy was selected as a candidate to replace NARloy-Z because previous research had revealed that this alloy exhibits excellent high-temperature strength, resistance to creep, and low cycle fatigue behavior, all combined with exceptional thermal stability. Specimens of 88Cu/8Cr/4Nb fabricated by powder metallurgy (PM) had been found to exhibit better mechanical properties at a temperature of 1,200 °C than does NARloy-Z at 1,000 °C. The problem then became one of determining whether the superiority of PM 88Cu/8Cr/4Nb would carry over to VPS 88Cu/8Cr/4Nb.

In the first stage of an effort to investigate the properties of VPS 88Cu/8Cr/4Nb, VPS parameters to obtain an optimal deposit of this alloy on a cylindrical substrate were developed, then VPS was carried out to form a shell with a wall thickness of 0.5 in. (1.3 cm), and length of 6 in. (15 cm). Samples were machined from the 88Cu/8Cr/4Nb shell and analyzed for density and hardness. Some of the samples were further treated by vacuum annealing and/or hot isostatic pressing (HIP) prior to analysis.

Fabrication Process	Post-Fabrication Treatment	Density, g/cm^3	Hardness, Rockwell B
VPS	None (Sample Tested As-Sprayed)	8.480	62.6
	Vacuum Anneal for 4 Hours at 1,750 °F (954 °C)	8.583	72.3
	Vacuum Anneal for 4 Hours at 1,750 °F (954 °C) and HIP for 1 Hour at Same Temperature	8.730	76.8
	HIP for 4 Hours at 1,750 °F (954 °C)	8.685	69.3
PM and Extrusion	None	8.660	70.9

Density and Hardness of Specimens of 88Cu/8Cr/4Nb were measured after various fabrication processes and treatments.

The table presents the results of these analyses. For comparison, the table also presents the results of previous research on extruded PM 88Cu/8Cr/4Nb. The comparison reveals that the density and hardness of VPS 88Cu/8Cr/4Nb treated with vacuum annealing and HIP were greater than those of extruded PM 88Cu/8Cr/4Nb. These superior properties of the VPS 88Cu/8Cr/4Nb are expected to translate into superior tensile and low-cycle fatigue properties; experiments to verify this expectation had not been completed at the time of reporting the information for this article.

This work was done by Richard R. Holmes and Frank Zimmerman of **Marshall Space Flight Center** *and George P. Beason, Jr., and Timothy N. McKechnie of Plasma Processes, Inc. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category. MFS-26546*

Etching Solution for Removal of Silver Plating From Polymers

Underlying polymeric materials are not attacked.

NASA's Jet Propulsion Laboratory, Pasadena, California

An etching solution has been developed for use in removal of silver plating from polymer-based (including composite-material) structural components, the surfaces of which are intended to serve as mirrors and waveguide structures. Such structures are often plated with aluminum, copper, and silver to impart the reflectivity and electrical conductivity required of mirror and waveguide surfaces. It is sometimes necessary to remove the plating in preparation for reworking mirror or waveguide hardware. The present etching solution satisfies a need for an effective, fast-acting, nonoxidizing plating-removal solution that does not destroy the underlying polymeric or composite material.

The present solution is a modified version of a previously developed and widely used copper chloride etching solution. During use of the previously developed solution, the plating is attacked by nonoxidizing chloride ions. The previously developed solution works well in removing most metals but is not suitable for use on silver because it leaves an insoluble silver chloride residue.

The present solution is a bright green liquid that consists of deionized water containing 5 percent by weight of cuprous chloride and 20 percent by weight (saturation concentration) of ammonium chloride. The addition of the ammonium ions prevents the formation of an insoluble silver chloride residue. Instead, ammonium ions form a complex soluble salt with silver; namely, silver ammonium chloride $[Ag(NH_3)_2Cl]$. A silver-plated polymeric or composite-material surface can be cleaned of all silver by immersion in this solution for as little time as 10 seconds. The solution also readily attacks most other metals — especially aluminum.

This work was done by Paul B. Willis of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category. NPO-20340*

Flutterometer for Flight Testing

Flight data are used to predict unstable flight conditions.

Dryden Flight Research Center, Edwards, California

A flutterometer is being developed for use as a data-analysis tool for flight flutter testing. The tool is based on an on-line implementation of a robust flutter analysis technique, called the "μ method," that was described in "Characterizing Worst-Case Flutter Margins From Flight Data" (DRC-97-03), *NASA Tech Briefs*, Vol. 21, No. 4 (April 1997), page 62.

Flight testing is performed to evaluate the characteristics of an aircraft and to determine a range of flight conditions, called a "flight envelope," in which an aircraft can be operated with safety. A particularly dangerous instability that one must avoid is flutter, which results from coupling between structural and aerodynamic forces. Flight flutter testing is flight testing for determining a safe flight envelope in which an aircraft will not exhibit a flutter instability.

Figure 1. The **NASA F/A-18 Systems Research Aircraft**, here shown high above Edwards Air Force Base, was mathematically modeled in a computational simulation to demonstrate the performance of the flutterometer.

In traditional methods of flight testing, one expands a flight envelope via a series of test points, using measurements (that is, sensor outputs) generated in response to some excitation. Such dynamical properties as damping are estimated from the measurement data, and trends are used to determine whether the envelope may be expanded further. These methods are inefficient, and to be able to use these methods, one must ensure that data points are closely spaced, inasmuch as the trends do not guarantee which increases in flight conditions may be safely considered. Also, flight flutter testing is potentially dangerous to the crew because an unexpected flutter instability (one not predicted from the trends) can occur during a transition to a new test point.

The μ method provides for computation of worst-case flight conditions for which flutter may occur, by considera-

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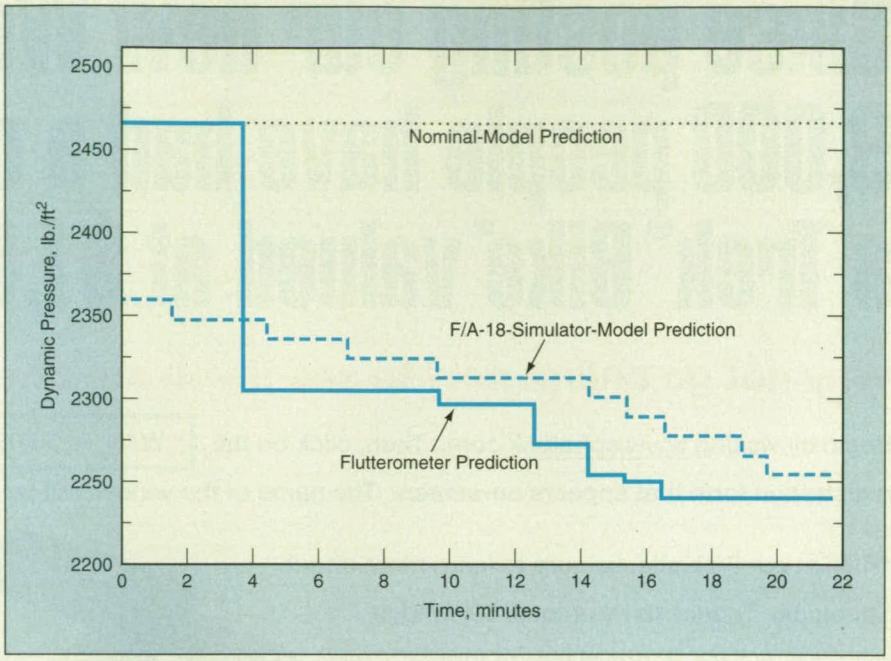


Figure 2. These **Plots Show the Dynamic Pressures** at which flutter was predicted to occur, as a functions of time, according to the flutterometer and to two mathematical models of the F/A-18 airplane.

tion of errors and uncertainty in a mathematical model. The flutterometer uses flight data to identify errors and uncertainty in a model, so the resulting worst-case flutter margins predicted by use of the μ method directly account for data that describe the aircraft (as distinguished from a mathematical model of the aircraft).

The flutterometer can reduce the risk and cost associated with flight flutter testing by predicting unstable flight conditions at a current test point in order to determine what increases in flight conditions may be safely considered for the next test point. The envelope expansion can proceed more rapidly, inasmuch as test points can be chosen on the basis of traditional, but unreliable, damping trends along with the additional information from flutterometer predictions.

A flight flutter test of the F/A-18 Systems Research Aircraft (see Figure 1), in which the envelope at mach 1.2 was expanded by decreasing altitude and increasing dynamic pressure, was simulated computationally to demonstrate the performance of the flutterometer. The F/A-18 mathematical model used in the simulation provided for a representation of temporal variation of mass corresponding to consumption of fuel, and for representation of measurements by wing-tip sensors. Another, nominal mathematical model of the F/A-18 airplane that includes 10-percent errors in structural stiffnesses and was formulated for constant mass corresponding to full fuel was used to predict unstable flight conditions for the simulated F/A-18.

Figure 2 shows the dynamic pressure at which flutter occurred as the simulation progressed. The dashed line represents the unstable flight conditions for the F/A-18 simulation; this line shows changes, even at constant-mach-number flight, because of the temporal variation of mass. The dotted line represents the traditional prediction, which was inaccurate inasmuch as it was based on the nominal model with no accounting for errors. The solid line represents the flutterometer prediction, which was computed by use of sensor data starting at 3 minutes (simulated time) after the beginning of the simulation to identify errors in the nominal model. These errors account for the unmodeled temporal variation of mass, so that the predicted worst-case flight conditions associated with flutter remain conservative to the true unstable conditions. The flutterometer could be used to determine safe test points for envelope expansion because the unstable flight conditions are predicted by use of data throughout the flight to account for unmodeled temporally varying dynamics.

This work was done by Rick Lind and Martin Brenner of **Dryden Flight Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Dryden Flight Research Center; (805) 258-3720. Refer to DRC-98-01.

Improved Mufflers for General Aviation

SiC foam serves as an absorber in a dissipative/reactive noise-suppression scheme.

Lewis Research Center, Cleveland, Ohio

Innovative designs of mufflers for engines of small airplanes have been investigated in an effort to satisfy conflicting demands to maximize the reduction of exhaust noise while minimizing back pressure, size, and weight. Automotive-type muffler designs are not suitable for this purpose because they entail excessive back pressures, sizes, and weights.

The investigation involved identification of key legal and technological issues in the silencing of general-aviation aircraft; development of a baseline theoretical approach to the design and optimization of aircraft engine exhaust systems; and evaluation of conceptual innovative designs of muffler and exhaust systems with dissipative, resistive, and reactive muffler components. The innovative designs call for the use of silicon carbide foam as a broadband absorber material in combination with reactive components; specifically, the designs feature variously sized and shaped expansion chambers with acoustic liners or flow-through baffles.

In experiments, acoustical impedances, resistances to flow, and other relevant properties of absorbers were measured and compared with theoretical predictions to determine such empirical parameters as structural factors. Noise characteristics of commercial aircraft engines were measured and compared with predicted values used in designing mufflers. Then prototypes of 17 different innovative muffler designs were fabricated, and several commercial aircraft engines were tested alternately with stock mufflers and with some of the prototypes to measure acoustic insertion losses as functions of frequency.

It was demonstrated that engine noise dominates overall aircraft noise for engines of less than 250 horsepower (power less than about 190 kW), and that mufflers can be beneficial toward reducing aircraft noise. Final flightweight designs had not been developed at the time of reporting information for this article. However, it was determined that because of the low frequencies of sounds generated by engines of the type in question, dissipative/reactive muffler designs like those investigated will be necessary for satisfying the noise, size, weight, and performance requirements of general aviation. An additional advantage of these muffler designs is that they are also highly suitable for incorporation of catalytic converters to reduce chemical as well as noise pollution.

This work was done by Andrew J. Sherman, Sangvavann Heng, and Edwin P. Stankiewicz of Ultramet for **Lewis Research Center**. *For further information, access the Technical Support Package (TSP) free on-line at www.nasatech.com under the Mechanics category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7–3, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16324.

Imaging System Shows Ischemic Regions

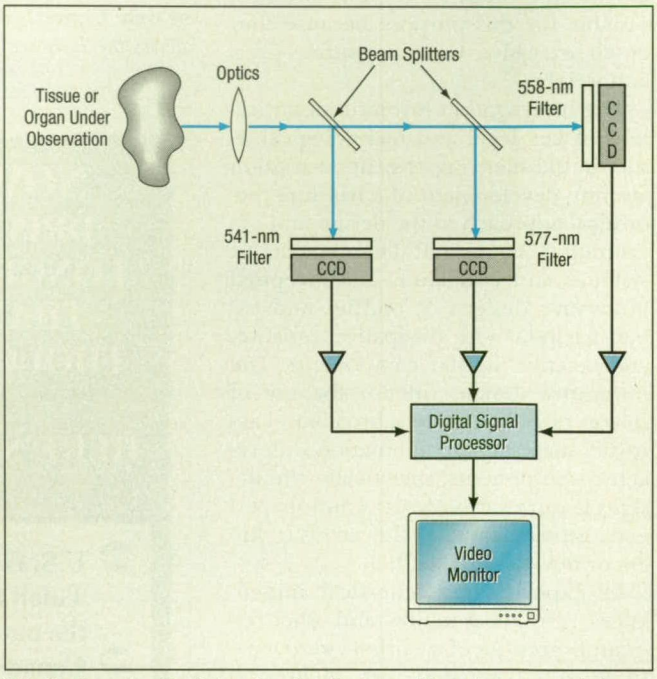
Real-time images help in monitoring and guiding treatments.

NASA's Jet Propulsion Laboratory, Pasadena, California

A noninvasive medical-imaging system produces false-color images that show regions of ischemia (reduced oxygenated blood flow) in organs and tissues. The system operates in real time, providing immediate guidance for surgery or other treatment. For example, the system can be used to identify tissues that should be removed in treating burns or in other surgical procedures.

The detection of ischemia involves the determination of the relative oxyhemoglobin and deoxyhemoglobin contents of blood in the affected organ or tissue. Heretofore, this has been done in nonimaging fashion by use of in-place monitors, such as pulse oximetry, which is not organ specific. The present noninvasive, real-time system is a multispectral imaging system that utilizes the spectral signatures of oxy- and deoxyhemoglobin.

The system (see figure) includes three charge-coupled-device (CCD) video cameras aimed at the same spot with the help of beam splitters. The light entering each camera passes through a narrow-band-pass filter at a unique wavelength. One possibility for wavelengths of the three filters is 541, 577, and 558 nm. These wavelengths were chosen because oxyhemoglobin has absorption peaks at 541 and 577 nm, while deoxyhemoglobin has an absorption peak at 558 nm. Another choice could include one of the one of the isobestic points. Thus, as oxyhemoglobin is converted to deoxyhemoglobin, the 541-nm and 577-nm absorption peaks become depressed and the 558-nm absorption peak appears. Another choice may be 558 (deoxy peak), 569, and 586 (isobestic points).



This **Noninvasive, Real-Time Imaging System** utilizes three spectral absorption peaks characteristic of oxy- and deoxyhemoglobin.

The images acquired simultaneously at the three wavelengths can be processed and combined in such a way as to enhance the spectral contrast between deoxyhemoglobin and oxyhemoglobin. For this purpose, the video outputs of the three cameras are fed to a digital signal processor (DSP), which produces a false-color (red/green/blue) image of the organ or tissue that shows blood oxygen content. The DSP uses an algorithm derived from clinical data. This false-color image is displayed on a video monitor.

This work was done by Gregory H. Bearman, Thomas G. Chrien, and Michael L. Eastwood of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Bio-Medical category.*

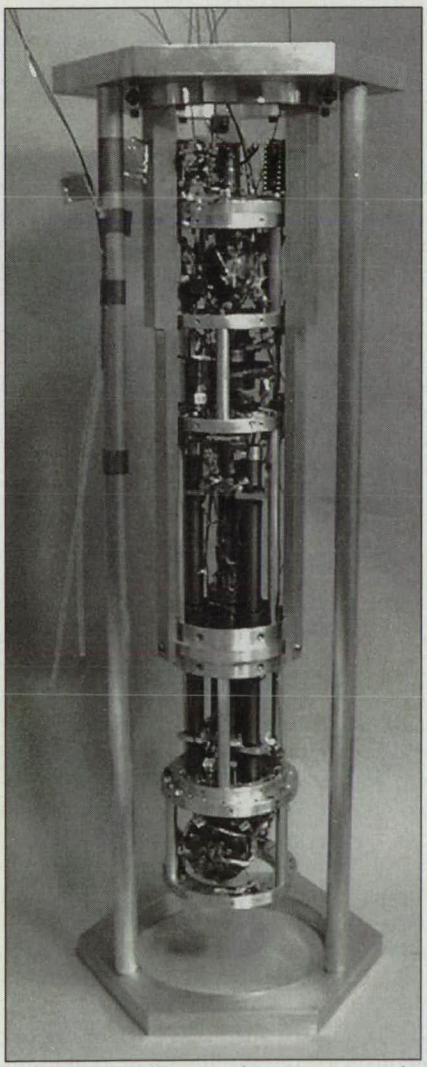
This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office–JPL; (818) 354-5179. Refer to NPO-19569.

Thermal-Isolation Structure for Low-Temperature Experiments

A tension/compression structure reduces thermal bias.

NASA's Jet Propulsion Laboratory, Pasadena, California

The figure shows a tension/compression structure that provides rigid suspension and a high degree of thermal isolation for a small instrument assembly used in low-temperature experiments. The structure is designed primarily for use in a microgravitational environment; specifically, to support a sensor package in the Critical Dynamics in Microgravity Experiment (DYNAMX), which is scheduled to fly on the space shuttle as part of the Microgravity Science Payload in early 2002. The structure also is adaptable to scientific experimentation in normal Earth gravity in cases in which there are requirements for lightweight, rigid, thermally isolating structures in confining geometries.



In this **Tension/Compression Structure** polymeric cords under tensile preload provide rigid suspension and thermal isolation of the suspended mass.

High structural rigidity is necessary for low-temperature scientific experimentation in the microgravitational environment of a spacecraft in a low orbit around the Earth. The rigidity is needed not only to withstand loads encountered during launch but also to prevent amplification of low-frequency vibrations from the spacecraft (typically, the space shuttle), which vibrations can generate heat in an instrument and thereby bias the results of an experiment. High levels of thermal isolation are needed, not only between the instrument and the spacecraft, but also between components within the instrument, to prevent thermal "crosstalk" and the biases that such crosstalk could engender. In the case of a highly sensitive low-temperature instrument, the need for thermal isolation dictates minimization of instrument-component masses to minimize the bias attributable to heat deposited by cosmic rays.

Heretofore, tension/compression structures have seldom been used in cryogenic applications, even though they offer enormous advantages in thermal isolation and rigidity. The present tension/compression structure includes a cylindrical exoskeleton, within which instrument components are held in position by tensioned Kevlar (or equivalent) aromatic polyamid cords. The combination of strength of the exoskeleton and preload in the cords provides rigid mounting for the instrument com-

ponents. Because the cross-sectional area of the cords is small and the thermal conductivity of the cord material is low, the cords provide a high level of thermal isolation. The narrowness and low density of the cords also limits the deposition of heat from cosmic rays.

A computational simulation was performed to compare the performance of this structure with the performances of mounting structures of conventional designs. The results of the simulation showed that this structure could provide a higher level of thermal isolation from surrounding structures and a lower level of thermal crosstalk between instrument components.

This work was done by Alfred Nash and Linda Robeck of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category. NPO-20338*

In Situ Chemical Analysis via Acoustic-Emission Spectra

Small piezoelectric sensors coated with reactive materials would provide data on chemical compositions.

NASA's Jet Propulsion Laboratory, Pasadena, California

A method of *in situ* chemical analysis by use of small, simple, robust sensors has been proposed. The basis for the proposal is the discovery that chemical reactions emit acoustic waves, and that characteristic frequency spectra are associated with specific reactions. The acoustic frequencies of interest range from about 0.1 to several megahertz. If a newly recorded acoustic spectrum were to match a previously recorded spectrum of a known chemical reaction, then the newly recorded spectrum would be deemed to indicate the presence of that reaction. The amplitude of a spectrum would be taken as an indication of the rate of the corresponding reaction.

A chemical-analysis instrument based on this concept would include an array of miniature piezoelectric acoustic sensors, each with a typical area of no more than a fraction of a square millimeter. The sensors would be able to withstand accelerations up to about 10^5 times that of normal Earth gravitation (about 10^6 m/s^2).

The instrument would include circuitry for flash analog-to-digital conversion of the sensor outputs, plus a moderately powerful digital data processor that would Fourier-analyze the digitized sensor outputs to obtain acoustic spectra. The instrument would also include electronic circuitry for (1) matching the newly acquired spectra with previously recorded spectra of known reactions and/or (2) recording and/or transmitting the newly acquired spectra for further processing by a computer to find matches to known spectra. The durations of typical chemical reactions of interest range from tens of seconds to hours; on this time scale, there would be no difficulty in time-multiplexing readouts from multiple sensors.

In the original proposed application, such an instrument would be used to find the chemical compositions of gases and dust in the Martian atmosphere, soil, and/or rocks. A similar terrestrial use would be monitoring gaseous, liquid, and solid pollutants in the field. For this purpose, the piezoelectric transducers would be coated with materials that engage in known chemical reactions with the pollutants or other substances of interest. Coatings could include adhesives to assist in collection of dust (and/or magnets to assist in collection of

magnetic dust). Alternatively or in addition, reactive liquids could be injected into reaction sites at analysis time. Because the sensors would have low thermal masses, heating the sensors to reaction temperatures (if necessary) would consume little power — no more than milliwatts at the highest temperatures likely to be needed.

This work was done by Frank Hartley of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category. NPO-20222*

Electrostrictive Thermal Break Between Superfluid Reservoirs

Superfluid in a connecting capillary would be rendered normal by electrostriction.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed technique would make it possible to maintain two reservoirs of superfluid helium at the same pressure but at different temperatures. Heretofore, a fountain effect (described below) has made this impossible. The proposed technique could be useful for low-temperature experimentation and for the general processing of liquid helium.

Liquid helium becomes a superfluid when cooled below a temperature of 2.177 K. One of the characteristics of a superfluid is nearly infinite thermal conductivity. Thus, if two reservoirs containing superfluid helium are put in fluid communication to equalize their pressures, thermal conduction through the connecting fluid equalizes their temperatures. Even a connection as narrow as a capillary tube acts as a thermal short circuit.

One way to obtain a temperature difference between the two reservoirs is to make the fluid connection through a porous material (e.g., a ceramic). However, such a temperature difference is accompanied by a pressure difference; this is the phenomenon known as the fountain effect.

According to the proposal, the two reservoirs would be connected via an electrically conductive capillary tube, part of the interior of which would be occupied by an electrically insulated wire. A high voltage would be applied between the wire and the capillary tube. The resulting high electric field inside the tube would cause electrostriction in the fluid, so that the pressure in the capillary tube would increase. The increase in pressure would depress the superfluid-transition temperature, causing the fluid in the capillary tube to revert to a normal fluid. Because the fountain effect would not occur in the normal fluid, it would be possible to maintain a temperature difference between the opposite ends of the capillary tube.

The increase in pressure with electrostriction is given by

$$P = (\varepsilon_0/6)(d-1)(d+2)E^2,$$

where ε_0 is the vacuum permittivity, d (which equals 1.06) is the relative permittivity of liquid helium, and E is the electric field. A suitable device to implement the technique could be made from a wire of 0.003 in. (0.076 mm) outside diameter and a tube of 0.004 in. (0.102 mm) inside diameter. At the breakdown electric field of 10^8 V/m, it should be possible to depress the superfluid-transition temperature by 0.23 mK.

This work was done by Talso Chui and Yury Mukharsky of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category. NPO-20406*

Processing ScanSAR Data Using a Chirp z-Transform

A phase-preserving algorithm generates images with selectable constant azimuthal pixel length.

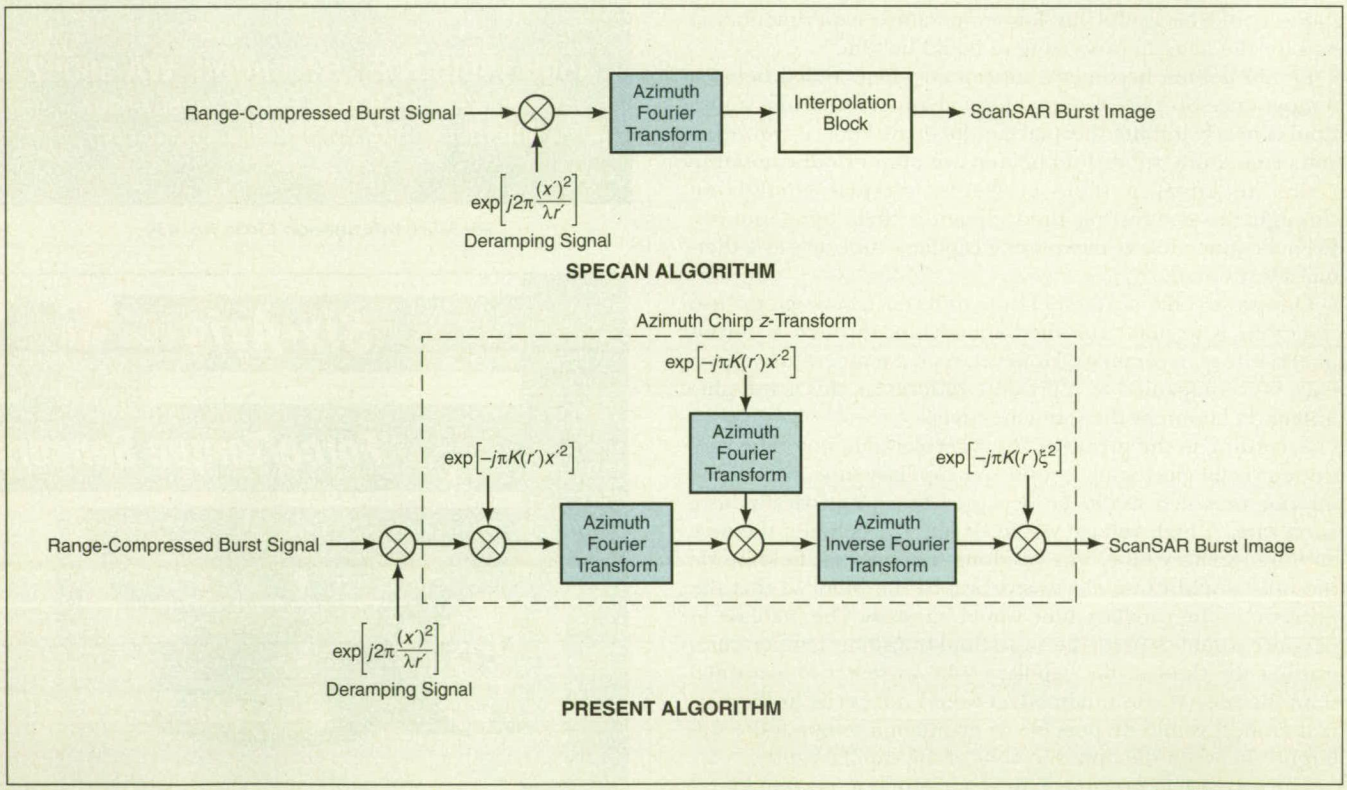
NASA's Jet Propulsion Laboratory, Pasadena, California

An algorithm that processes bursts of data generated by scan-mode synthetic-aperture radar (scanSAR) offers some advantages over older scanSAR algorithms. With relatively high computational efficiency, the algorithm can shift and scale the position along the flight track, preserve the phase of the radar signal, and provide for immediate formation of interferograms from two radar images.

swath is arbitrarily long in the azimuth (along-track) direction; as a result, the finest achievable resolution in azimuth (the along-track coordinate) is independent of range (radar/target distance) and equals half the along-track dimension of the antenna. High range resolution is obtained by use of either very short pulses or properly coded signals. The length of the range swath is limited by the pulse-repetition interval; in some applications, this can be undesirable.

In the scan mode, the radar beam is periodically stepped in range to neighboring swaths, which are denoted subswaths for scanSAR purposes. This stepping increases the length of the range swath, but exerts the undesirable effect of decreasing along-track resolution because the stepping prevents the collection of the return from a target along the full along-track synthetic antenna aperture length dimension of the synthetic aperture. The term "burst" is used to characterize both (1) the interval during which the radar beam illuminates a given subswath and (2) the data obtained from the subswath.

ScanSAR data could be processed following a standard range/Doppler approach that includes, among other things, the use of Fourier transforms for efficient frequency-domain implementation of convolutions. However, for reasons too complex to discuss within the limits of this article, this approach entails large zero-padding of burst data in preparation for azimuth compression, and this padding makes for computational inefficiency. An alternative approach is implemented by a very effi-



The **Present Algorithm Is Derived** from the SPECAN Algorithm. The standard Fourier transform of the SPECAN algorithm is replaced with a chirp *z*-transform, the kernel of which includes the range-dependent correction (scaling) factor $K(r') = r'_0/r'$, where r' is a range variable and r'_0 is a fixed range computed from the desired azimuthal pixel length. Regarding the other algebraic symbols: x' is an azimuthal coordinate, λ is the wavelength of the radar signal, and ξ is an azimuthal spatial frequency often interpreted in terms of Doppler frequency.

Conventional practice in synthetic-aperture radar (SAR) involves the use of either the scan mode or the strip mode. The most commonly used mode is the strip mode, in which the radar antenna is pointed in a fixed direction with respect to the flight track and the illumination footprint covers a strip on the ground as the radar system moves along the flight track. The mapping

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cient algorithm called "SPECAN," in which azimuth focusing is accomplished in a process that involves a phase-multiplication operation called "deramping," followed by a Fourier-transform step. This process involves the original burst data with either no zero padding or very limited padding to the nearest power of 2 for a typical discrete-Fourier-transform code. Strictly speaking, the SPECAN algorithm does not compensate for range migration, but partly as a consequence of the shortness of bursts, the range-migration effects in most scanSAR applications are small enough that one can ignore them for practical purposes.

The present algorithm is an extended version of the SPECAN algorithm (see figure). One relevant characteristic of the SPECAN algorithm is the need for range-dependent scaling of the along-track pixel dimension. This scaling is accomplished in a post-processing interpolation step that can degrade either computational efficiency or accuracy, depending on the length of the interpolation kernel. In the present algorithm, the need for the scaling and post-processing interpolation is eliminated by replacing the standard Fourier transform of the SPECAN algorithm with a chirp z-transform, the kernel of which includes a range-dependent correction (scaling) factor. The chirp z-transform can be computed by use of fast-Fourier-transform software, without need for zero-padding; however, the present algorithm is somewhat less efficient than the SPECAN algorithm is because the chirp z-transform involves a convolution rather than a simple Fourier transform.

The present algorithm is fully phase-preserving and retains the relative simplicity and most of the computational efficiency of the SPECAN algorithm. However, unlike the SPECAN algorithm, the present algorithm automatically generates images with constant azimuthal pixel length, without interpolation; moreover, the azimuthal pixel length can be chosen to suit the application at hand.

This work was done by Riccardo Lanari, Scott Hensley, and Paul Rosen of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Information Sciences category. NPO-20389*

Neutrophil-Screening Assay Using Two-Color Flow Cytometry

This test can be performed rapidly and yields quantitative data.

Lyndon B. Johnson Space Center, Houston, Texas

An *in vitro* test that includes the use of two-color flow cytometry has been developed for use in screening of neutrophils for their ability to fight infections. Neutrophils constitute the first line of defense of the human body against infections. Neutrophils engulf invading bacteria in a process called "phagocytosis." The primary means by which they destroy the bacteria is the production of hydrogen peroxide and toxic oxygen radicals; this production is called "oxidative burst." Acquired defects in phagocytosis or oxidative burst can allow localized or generalized infections to develop. Such defects can be caused by toxins, drugs (including adrenocorticosteroids), and/or radiation. A rapid test that yields data on such defects could be helpful in choosing appropriate therapeutic measures prior to onset of overt clinical disease.

Most of the older *in vitro* tests developed for the same pur-

pose require microscopy, are time-consuming, and involve much subjective judgement by highly trained technicians. One of the older tests is less subjective in that it yields quantitative data via an absorbance-spectrophotometric measurement of concentration of dye extracted from stained cells, but the disadvantage of this older test is that it requires a large amount of blood (as much as 10 mL). In contrast, the present test can be performed relatively quickly, requires a small amount of blood, and yields quantitative data.

In the present test, one uses stained cells of two species; the opportunistic pathogen *Candida albicans* and the intracellular pathogen *Listeria monocytogenes*. *Candida* is a common commensal that can cause serious disease if immunological defects occur. *Listeria* is a catalase-producing organism that is not killed after phagocytosis if there is a defect in oxidative burst. (*Listeria* is used routinely in immunotoxicity testing.) Batches of *Candida* and *Listeria* organisms are stained with one of three fluorescent dyes (fluorescein isothiocyanate, CellTracker™, or Mitotracker™) for the purpose of testing for phagocytosis of those organisms. Neutrophils are stained with either of two other fluorescent dyes (dichlorofluorescein diacetate or hydroethidine) to detect oxidative burst with respect to those organisms.

In preparation for the test, the three types of cells are stained, then washed to remove excess dye. Neutrophils are mixed with cells of the other two types, and each mixture is incubated in a tube at an appropriate temperature. After an appropriate time (e.g., 1 hour), the incubation is stopped by putting the tubes on ice. A dilute suspension of cells in liquid is made from each mixture, and a jet of the liquid is made to cross a beam of light of wavelength 488 nm generated by an argon-ion laser in a flow cytometer. By use of photodetectors and band-pass filters in combination with a dichroic mirror, intensities of red and green fluorescence are measured, both in the forward- and perpendicular-scatter directions. These measurements are processed to determine the percentage of fluorescent neutrophils and the peak modal channel of fluorescence of the neutrophils. They are also used to generate a display of fluorescence intensities in a histogram or in a two-color contour plot.

This work was done by Duane L. Pierson of **Johnson Space Center** *and Raymond P. Stowe and Saroj K. Mishra of KRUG Life Sciences. For further information, access the Technical Support Package (TSP)* ***free online at www.nasatech.com*** *under the Bio-Medical category.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center, (281) 483-0837. Refer to MSC-22654.

Apparatus for Faster Ultrasonic-Lamb-Wave Testing

Data on the stiffness properties of a specimen can be acquired within seconds.

NASA's Jet Propulsion Laboratory, Pasadena, California

An ultrasonic-transducer fixture containing multiple pairs of fixed transducers, plus associated electronic transducer-multiplexing circuitry have been developed to accelerate the acquisition of data on the dispersion of ultrasonic leaky Lamb waves (LLWs) in plate specimens of laminated composite (matrix/fiber) materials. The fixture and multiplexing circuitry can readily be incorporated into a previously constructed ultrasonic-LLW system that contains a single pair of movable ultrasonic transducers.

LLWs are guided waves that propagate along the surfaces of the specimens. In a typical conventional ultrasonic-LLW system, a plate specimen is immersed in water (which serves as an acoustic-coupling medium), with a transmitting and a receiving ultrasonic transducer positioned above the specimen in a pitch/catch arrangement at a specified angle of incidence, as shown in Figure 1. For each of several angles of incidence, the output of the receiving transducer is digitized and processed to extract reflection-spectrum and dispersion data. These data are then inverted, by use of special-purpose software, to obtain the coefficients of elasticity of the materials and to evaluate flaws in the specimens.

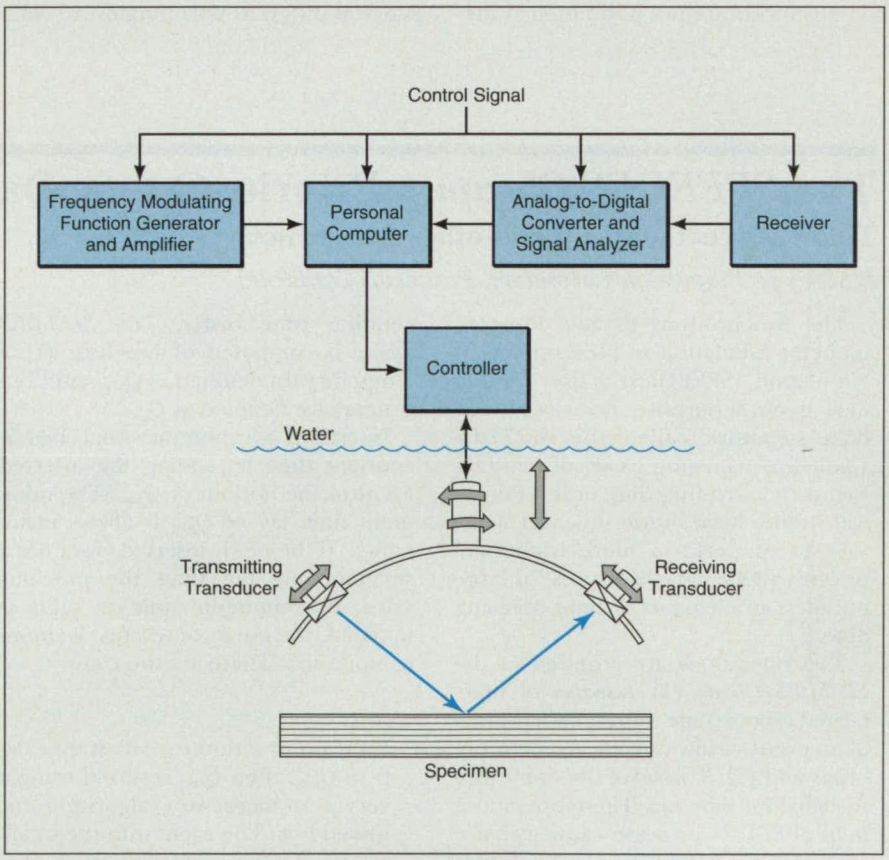

Figure 1. In a **Conventional Ultrasonic-LLW System**, the transmitting and receiving transducers must be moved to different positions to obtain different angles of incidence.

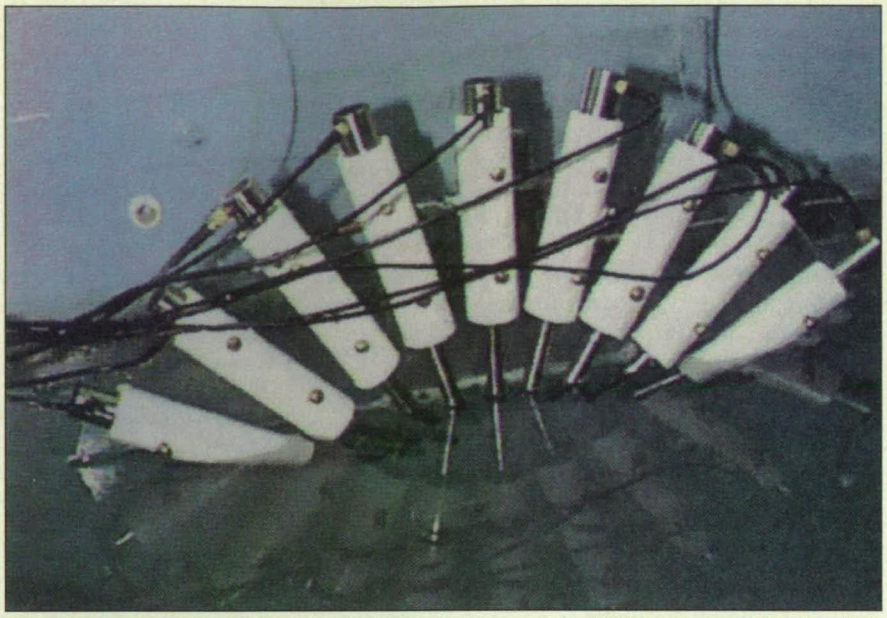

Figure 2. **Transmitting/Receiving Pairs of Ultrasonic Transducers** in this fixture are positioned and oriented, relative to an immersed specimen, for angles of incidence of 15°, 30°, 45°, and 60°.

In the conventional system, the speed of acquisition of data is limited by the need to reposition the transducers to obtain different angles of incidence. In a system equipped with the present fixture and multiplexing circuitry, data can be acquired much more rapidly because except as explained in the next paragraph, the transducers are not repositioned during a test; instead, multiple transmitting/receiving pairs of transducers are pre-positioned at the desired angles of incidence (see Figure 2) and are switched into and out of operation in the required sequence during a test by use of the multiplexer circuits under control by a computer. The software for controlling the multiplexer circuits is part of a modified version of the software for controlling the rest of the ultrasonic-LLW system.

In some cases, it could be necessary to acquire data with the plane of incidence at different polar angles (0°, 45°, and 90°) with respect to fibers projected onto the surfaces of the specimens in order to characterize the specimen materials completely. Even in such a case, it is not necessary to expend much time repositioning transducer pairs; all one need do is rotate the transducer fixture to each polar angle and to perform the measurement sequence there. Experiments have shown that dispersion data for four angles of incidence at one given polar-angle setting could be acquired in 7.4 seconds.

This work was done by Yoseph Bar-Cohen of Caltech and Susan Kersey, Cedric Daksla, and Anatoly Blanovsky of UCLA for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

Technology Reporting Office
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Mail Stop 122-116
4800 Oak Grove Drive
Pasadena, CA 91109
(818) 354-2240

Refer to NPO-20400, volume and number of this NASA Tech Briefs *issue, and the page number.*

The *SPEEDES Qheap*: A Priority-Queue Data Structure

This construct outperforms other data structures.

NASA's Jet Propulsion Laboratory, Pasadena California

The Synchronous Parallel Environment for Emulation and Discrete-Event Simulation (SPEEDES) is now using a new general-purpose priority queue data structure called the *SPEEDES Qheap* for managing its set of pending events in ascending time order. Empirical studies have shown this data structure to outperform more traditional priority queue data structures for large numbers of elements without breaking down.

Two operations are required of the *SPEEDES Qheap:* (1) *Insertion* of time-tagged events (time represents a priority of an event — low time means high priority) and (2) *Removal* of the event with the smallest time tag. These operations help SPEEDES preserve causality since events, which may generate future events, must always be processed in ascending time order. The *SPEEDES Qheap* is composed of two lists: (1) a temporary list denoted *as* Q_{temp} and (2) a primary list denoted as Q_{heap}.

Insertions are always accomplished in constant time by adding the inserted event to the bottom of Q_{temp}. The minimum time tag of Q_{temp} is always maintained. If the newly inserted event has a smaller time tag than the previous value, the minimum time-tag value is updated. Removal of events is more complicated. There are two cases.

Case 1:

If the event with the smallest time tag is in Q_{temp}, then Q_{temp} is sorted using a very fast merge-sort algorithm for linked lists. The event with the smallest time tag is removed from Q_{temp} and returned as the next event. The rest of Q_{temp} is Metasized into a single Metaitem that is inserted into Q_{heap}. Note that the newly formed metaitem is actually a sorted list of events. The time tag of the metaitem is defined as the time tag of the first event in its sorted list. If the number of metaitems in Q_{heap} ever grows larger than a specified value, S, then the metaitems in Q_{heap} are further metasized into a single metaitem so that the number of metaitems in Q_{heap} is reduced back to one. This helps keep Q_{heap} small enough so that straight insertion of metaitems remains efficient. Metaitems may contain lists of other metaitems, which can contain lists of other metaitems, etc. In this way, Q_{heap} is a recursively linked list data structure that adheres to the heap property.

Case 2:

The event with the smallest time tag is in Q_{heap}. This is more difficult since it is possible that the item removed from the top of Q_{heap} is actually a metaitem itself. If this is so, then the metaitem must be untangled by removing its top item, redefining the rest of the list of the metaitem as a new metaitem, making sure that Q_{heap} does not have more than S elements (if it does, then the elements in Q_{heap} are turned into a single metaitem and placed back into Q_{heap} as a single element), and then inserting this new metaitem back into Q_{heap}. The untangling procedure is repeated until a single event is obtained.

Because heaps are known to have worst-case $log_2(n)$ amortized behavior, this data structure should never break down. Also, because it is composed exclusively of linked lists, it should have very low overheads. There are no complicated rotation operations or arbitrary balancing heuristics to apply. This data structure does not require resizable arrays or modular arithmetic schemes either. The only (slightly) complicated part of the *SPEEDES Qheap* is the untangling procedure (which is actually very straight-forward). Because of its nice properties, the *SPEEDES Qheap* is highly recommended for general-event list management in discrete-event simulations and for other applications that require general-purpose priority queues. Provided below is a step-by-step procedure for implementing the *SPEEDES Qheap*.

SPEEDES Qheap Insertion

1. Place the event to be inserted at the end of the Q_{temp}.
2. Update T_{min} if this item has the smallest time tag out of all the items in Q_{temp}.

SPEEDES Qheap Removal

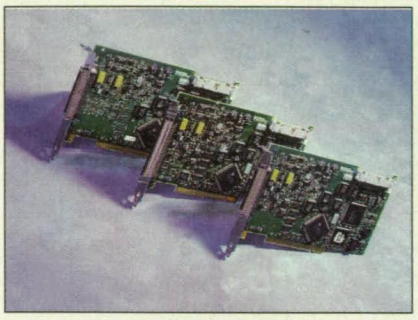
1. Check if T_{min} is less than the time tag of the next item in Q_{heap}. If so, perform steps a through f and then return. Otherwise, go on to step 2.
   a. Sort Q_{temp} and then set T_{min} to infinity.
   b. Remove the top element (this is what is returned as the next event) and call it *NextEvent*.
   c. Metasize the rest of the elements from Q_{temp} into a new metaitem called $Meta_{temp}$.
   d. Check if Q_{heap} already contains S elements. If it does, metasize all of its elements into a new metaitem and place it back into Q_{heap} as its only element.
   e. Insert $Meta_{temp}$ into Q_{heap}.
   f. Return *NextEvent*.
2. Remove the top item from Q_{heap} and call it *NextItem*. Then loop over steps a through e below until *NextItem* is not a metaitem.
   a. Check if *NextItem* is a metaitem. If not, then break out of the loop and return *NextItem* as the *NextEvent*. Otherwise, we know that *NextItem* is a metaitem which must be untangled in the steps b–e below.
   b. Remove the top element from *NextItem* and call it *NewItem*. *NextItem* now contains one less item. If *NextItem* has only a single element, then unmetasize it so that *NextItem* is a regular item.
   c. Check if Q_{heap} already contains S elements. If it does, metasize all of its elements into a new metaitem and place it back into Q_{heap} as its only element.
   d. Insert *NextItem* into Q_{heap}.
   e. Set *NextItem* = *NewItem* and then go back to a.

This work was done by Jeffrey S. Steinman of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Information Sciences category. NPO-20095*

FieldWorks, Eden Prairie, MN, has introduced the FW2000 Series Embedded Vehicle System (EVS) for **mobile data acquisition** applications. The NEMA 4X-rated system includes a server, daylight-readable display, and backlit keyboard. The server and user-interface components — keyboard, display, CD-ROM and floppy drives, which mount behind the display — are not in the same box, so users can mount the server in a remote location within the vehicle, with the interface components near the driver. The system can accommodate up to 270 peripherals.

The system can link to vehicle engine and subsystem electronics to collect and communicate performance information. Connectivity is accomplished via two PC card slots, three serial ports, one parallel port, and dual-channel Universal Serial Bus (USB). Other features include a 10.4" display and Pentium MMX processors to 266 MHz.

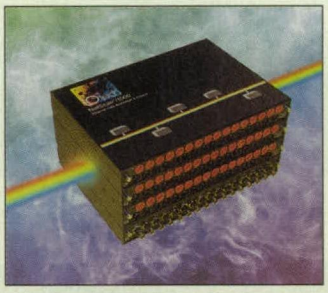
For More Information Circle No. 704



The E-Series of multifunction **data acquisition boards** from National Instruments, Austin, TX, features PCI bus-master ASIC for maximizing system performance; 20-MHz, 24-bit counter/timer ASIC; 2 microsecond settling amplifier; and a multiboard, real-time synchronization bus. The boards integrate with LabVIEW™ and LabWindows™/CVI software.

The 6023E, 6024E, and 6025E are 12-bit, 200 kS/s plug-in boards with 16 single-ended and eight differential analog input channels. The 6024E and 6025E also feature two 12-bit analog output channels. All boards feature two 24-bit, 20-MHz counter-timers, eight digital I/O lines, digital triggering capability, and a shielded latching metal connector. The 6025E also includes an additional 24 lines of digital I/O.

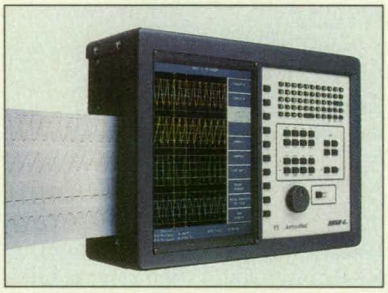
For More Information Circle No. 711



IOtech, Cleveland, OH, has released NetScan™/1500, an Ethernet-based **data-logging and control instrument** designed for isolated, high-channel-count measurements. Offering from 16 to 128 isolated analog input channels, the system monitors temperature, AC or DC voltage, pressure, and other analog or digital inputs. It features 32 control outputs that can be programmed to update via network control or to automatically respond to pre-programmed limits.

Other features include built-in temperature measurement capability, 200V channel-to-channel isolation, and an internal memory that continues to log data even if network service is interrupted. It can be placed anywhere on an existing Ethernet Local Area Network (LAN) or Wide Area Network (WAN). The system has four slots that accept 16-channel plug-in scanning modules, for a total of 64 channels.

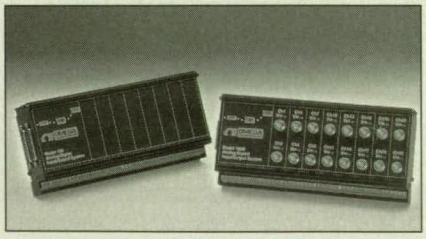
For More Information Circle No. 709



The Dash 4u four-channel **data acquisition field recorder** from Astro-Med, West Warwick, RI, is equipped with universal inputs that accept isolated single-ended, differential and high voltage, thermocouples, RTDs, DC bridge, and frequency-to-voltage conversions. Other features include a 10.4" active color LCD monitor, two additional channels for real-time mathematics, uninterruptible power supply, internal 4-GB hard drive, and a built-in 100-MB removable Zip drive for data transfer, archiving, and software updates.

The unit displays and records four channels of real-time data at frequencies up to 5 kHz. It also captures data to the internal hard drive for subsequent playback and review. The system comes with Windows-based AstroSET™ software for test setups, and AstroVIEW C™ software for data transfer, review, and analysis on a PC.

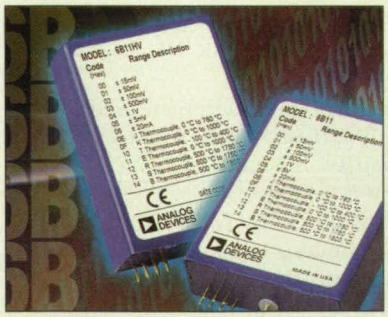
For More Information Circle No. 710



OMEGA Engineering, Stamford, CT, has introduced the InstruNet Series distributed **data acquisition system** for Windows 95/NT and Macintosh computers. The system utilizes a controller board plugged into the computer, and external A/D boxes for direct connection to thermocouple, RTD, voltage, thermistor, bridge, and strain sensors. Each external A/D box has 16 single-ended and eight differential analog inputs, eight analog outputs, and eight digital I/O.

Each controller card can connect up to 16 external A/D boxes that can be placed on a network up to 1000 feet away from the computer, for a total number of 256 analog inputs, 128 analog outputs, and 128 digital I/O. The system includes strip/chart software and drivers for C, Visual Basic, HPVEE, and TestPoint. Optional LabVIEW drivers are available.

For More Information Circle No. 702



Analog Devices, Norwood, MA, offers the 6B Series of **data acquisition modules and boards** for use in remote data acquisition and analog signal conditioning. The sensor-to-host system is designed for distributed I/O applications, supporting up to 255 I/O channels from a single communications port, spread out over thousands of feet. The modules are software-configurable for input range and sensor type, including analog input and output, and digital I/O.

Output data is transmitted over an RS-232C or multi-drop RS-485 serial communications link using twisted-pair wiring. The input/output modules are fully encapsulated and identical in pin-out and size, facilitating their ability to be mixed and matched with other modules on the same backplanes.

For More Information Circle No. 705

Books & Reports

Experiments on Flow in a Model Compressor Drum

A report discusses experiments on the flow of water along the interior of a transparent rotating cylindrical drum, the interior of which was partitioned into five cavities by disks with central holes and outer edges attached to the cylindrical drum wall. This water-flow model was designed to provide insight into the flow in the compressor drum cavity of an advanced, high-thrust engine. In the experiments, laser Doppler velocimetry was used to measure flow velocities.

This work was done by David G. N. Tse of Scientific Research Associates, Inc., for **Lewis Research Center**. *To obtain a copy of the report, "Experimental Simulation of Buoyancy Effect Using Two Liquids in Turbomachinery Components," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7–3, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16449.

Performance of an Arc-Jet Thruster

A report discusses the design and testing of a laboratory-model arc-jet thruster designed to operate at a nominal power level of 300 W. This thruster is an intermediate product of continuing efforts to develop smaller, lower-power, higher-specific-impulse thrusters for use in a forthcoming generation of small communication and scientific satellites. The thruster features a modular design, with a nozzle geometry chosen to promote supersonic-arc attachment.

This work was done by John M. Sankovic of **Lewis Research Center** *and David T. Jacobson of Ohio State University. To obtain a copy of the report, "Performance of a Miniaturized Arcjet," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Machinery/Automation category.*

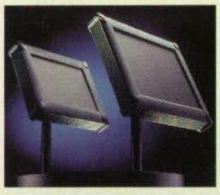
Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7–3, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16503.

New on the MARKET

Scan Converter for RGB Signals

RGB Spectrum, Alameda, CA, offers the UDC™ 100, real-time scan converter for up- or down-converting RGB signals. The system accepts RGB inputs up to 1280 x 1024 pixels and converts them to any other RGB format. The UDC is designed so that users can change signal characteristics to meet the requirements of any application. It accepts and converts signals from 15 to 90 kHz horizontal scan rate to any signal in the same range. Output signal can be synchronized and locked to an external reference. Pan and zoom functions allow extraction of any portion of the original signal for cropping or aspect ratio adjustment. **Circle No. 735**

Ruggedized Computer Equipment

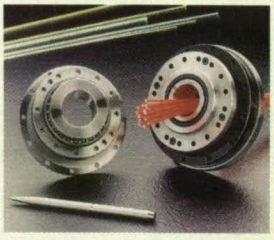


The SharkView™ series of industrial flat-panel displays and computer systems from Dolch Computer Systems, Fremont, CA, features case frames made from a proprietary high-strength finned aluminum extrusion. The display is mounted using the Dolch-designed IsoKlip™, which provides a tightly controlled amount of pressure. SharkView active matrix color displays are available in 12.1" SVGA (800 × 600), 15.1" XGA (1024 × 768), and 18.1" SXGA (1280 × 1024). An optional industrial single-board, Pentium® MMX-based computer and integrated hard drive are available. Applications include military, aerospace, medical, transportation-related, and industrial operations. **Circle No. 739**

Workstations Feature 450 MHz Processor

The TDZ® 2000 GX1 ViZual Workstation family from Intergraph Computer Systems, Huntsville, AL, supports Intel's 450 MHz Pentium II Xeon processors. The workstations also offer 2D and 3D graphics subsystems, including Intergraph's Intense 3D Pro™ and RealiZm™ II 3D Graphics. An upgrade program allows customers to upgrade Xeon-based systems to Intergraph's next-generation Wildcat 3D Graphics Technology. Other features include Intel's 440GX chipset and AGP graphics bus, 2 GB of RAM, 100 MHz SDRAM memory, and Wide Ultra2 LVD SCSI disk controller for data transfer rates to 80 MB/second. **Circle No. 737**

Hollow Shaft Speed Reducers



HD Systems, Hauppauge, NY, offers zero-backlash harmonic drive gearing designed so that shafts, wires, or tubing can pass directly through the center of the gear. Available as a component set or a housed unit, the SHF series unit design utilizes a patented "S" tooth profile that makes it axially shorter and lower in weight. Machine designers can incorporate SHF component sets directly into their equipment. The housed version incorporates an output flange supported by a large-diameter cross roller bearing. Gear reduction ratios range from 50:1 through 160:1 in a single stage. The reducers have a rated output torque of 590 in-lbs and a momentary peak torque of 2780 in-lbs. **Circle No. 738**

Power Cords and Connectors

Adam Technologies, Union, NJ, a Methode Electronics company, offers power cords and IEC inlet/outlet connectors designed according to IEC-320 and CEE-22 specifications. IEC inlet/outlet connectors are available in PC board and panel-mount versions. Terminations include PC tails, quick-connect terminals, and solder lugs. The UL-recognized, CSA-certified products are approved for use by VDE, SEMKO, SEV, SETI, NEMKO, DEMKO, KEMA, and BIS. Customized power cords and IEC inlet/outlet connectors are also available. **Circle No. 743**

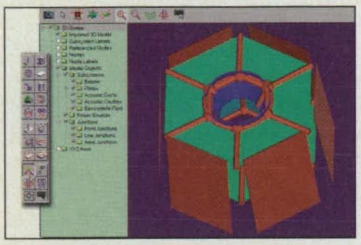
MPEG Transmission Systems

The MPEG Shuttle™ from Computer Modules, Santa Clara, CA, is a series of turnkey MPEG-1 and MPEG-2 transmission systems. The series integrates commercial MPEG encoders to Computer Modules' high-speed communications cards with TCP/IP, T1/T3, E1/E3, or RS422 interfaces. A custom GUI front end displays line error conditions and statistics in real time. The system uses the Windows NT operating system, and is designed to adapt to new devices and standards as they emerge. **Circle No. 741**

New on DISK

Noise and Vibration Analysis

Vibro-Acoustic Sciences, San Diego, CA, has announced AutoSEA2 noise and vibration analysis software that enables engineers to conduct a full system-level assessment of noise and vibration behavior. The software uses the probabilistic engineering methods of Statistical Energy Analysis (SEA) and room acoustics. This requires simpler model restructuring, thereby speeding the process. The statistical-analysis method predicts the expected mean noise-and-vibration behavior, averaged over uncertainty in the as-built system dynamics and/or uncertainty in design details at the concept stage. AutoSEA2 also features a 3D environment to facilitate modeling building. **Circle No. 717**

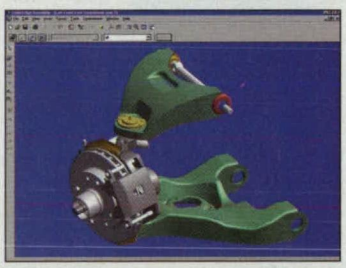


SystemView With MATLAB

Elanix, Westlake Village, CA, offers a library integrating its SystemView™ system-level design tool with MATLAB from The MathWorks. The library enables execution of MATLAB M and MEX-files as part of SystemView simulations; it also allows importing and exporting of data between the two tools. Algorithms developed in MATLAB can be incorporated into SystemView simulations of complete systems. MATLAB function parameters can be changed dynamically during simulation runs using SystemView's global parameter links. Designers can then algebraically link MATLAB function parameters to SystemView system variables such as system time or sample rate. **Circle No. 712**

Enhanced Product Design

Solid Edge V6 from Unigraphics Solutions, Huntsville, AL, is designed to fully exploit STREAM technology. This architecture captures designers' intentions through inference logic and decision-management concepts. Version 6 features include enhanced plastics, sheet-metal design, and rendering capabilities. The Virtual Studio module adds raytrace rendering, phong shading, 3D input-device support, fly through, and save-as-movie AVI capabilities. Plastics+ includes a lip feature, divide part, and cavity generation. The Sheet Metal+ module adds deformation features, jog, lofted flange, and other capabilities. **Circle No. 715**



Solids Manufacturing/Design

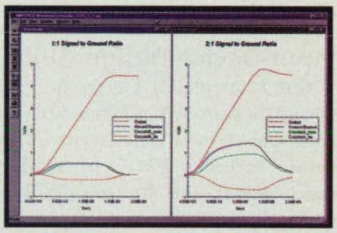
Bravo® Version 7.0 solids manufacturing and design software from Applicon, Ann Arbor, MI, supports "top down" design in which the engineer begins a project by creating the overall assembly. Each part is then developed using geometries and form features without leaving the assembly model. The software allows solids parts to be internalized from existing library items as a starting point for new designs. New control pick options enable users to change an arc radius, the display attributes of geometry, a crosshatch pattern, or text attributes. The program also incorporates Spatial Technology's ACIS V4.1. **Circle No. 714**

Embedded Development Tools

TNT Embedded ToolSuite® from Phar Lap Software, Cambridge, MA, provides support for Microsoft® Visual C++® 6.0, a component of the Microsoft Visual Studio™ 6.0 development system. The core of the embedded and real-time programming toolkit is the Realtime ETS Kernel, which enables developers to use the C/C++ compiler and IDE combination to build embedded and real-time software in conjunction with a hard, real-time, scalable RTOS. **Circle No. 718**

Signal-Integrity Simulator

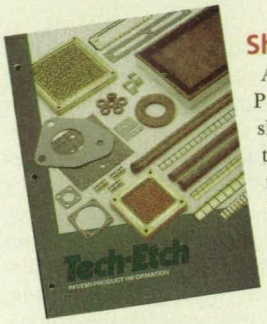
The Connector Noise Signal Integrity Simulator (CSIS) high-accuracy simulation software tool from AMP, Harrisburg, PA, is designed for identifying and preventing connector signal integrity problems in multi-board interconnection systems. It allows design engineers to perform "what-if" simulations during the early design stages, enabling them to select the best connector and signal-to-ground termination pattern. The CSIS has an intuitive GUI with an AMPSPICE™ simulation engine and a library of validated AMP connector models. Also included are comprehensive applications and design tutorials to assist engineers new to signal-integrity simulation. **Circle No. 721**



New LITERATURE

Data Acquisition & Instrumentation

Gage Applied Sciences, South Burlington, VT, has released a CD-ROM catalog encompassing the company's complete product line along with 100 application notes and articles. The free CD-ROM contains A/D cards for PCI and ISA Bus, digital input boards for PCI and ISA, software, instrument-grade PCs, and accessories. Application notes deal with subjects such as test and measurement and PC-based data acquisition. **Circle No. 726**



Shielding Products

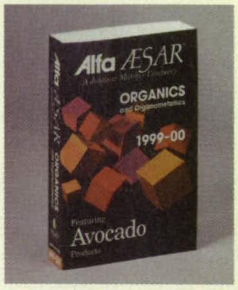
A 44-page catalog from Tech-Etch, Plymouth, MA, describes RFI/EMI shielding products for electronic applications, including doors, panels, connectors, and enclosures. Featured are beryllium copper finger stock strips, panel and strip gaskets, and board level shielding. **Circle No. 724**

Input-Device Design Guide

GM Nameplate's Electronic Products Group, Seattle, WA, offers a design guide for input devices. The Keypanel Design Guide includes EPG's Intaq® Electrotouch membrane switches, PCB switch assemblies, elastomer key panels, and transparent touchscreens. It also lists examples of switch-panel constructions. **Circle No. 725**

Organics and Organometallics

Alfa Aesar, a Johnson Matthey Company, Ward Hill, MA, has published the 1999-2000 edition of its Organics and Organometallics Catalog. It offers more than 10,000 products for organic chemists, including over 3,000 new items. The catalog includes increased physical-property data, expanded cross-references and synonym listings, a molecular-formula index, and Chemical Abstract Service (CAS) registry number index. **Circle No. 729**



Planetary Gearheads

A 92-page Product Selection and Engineering Guide, including True Planetary Gearheads, is available from Thomson Micron, Ronkonkoma, NY. Products include in-line and right-angle gearheads in addition to RediMount motor-mounting systems, flexible steel bellows couplings, and programmable limit switches. **Circle No. 730**

Rugged Valve Connectors

A brochure from TURCK, Minneapolis, MN, details DIN 43650 valve connectors and junctions. DIN 43650 Valve Connectors feature solid injection-molded polyurethane connector bodies designed for resistance to oil and abrasion. Snap-in labels identify the function of each valve. **Circle No. 731**

Test Equipment

Tektronix, Beaverton, OR, has released a 700-page 1998-99 Measurement Products Catalog featuring more than 70 new products, including the Digital Phosphor Oscilloscope (DPO) for design engineering, manufacturing, service, and communications applications. Also described are logic analyzers, VXI systems, and a variety of telecommunications test solutions. **Circle No. 733**

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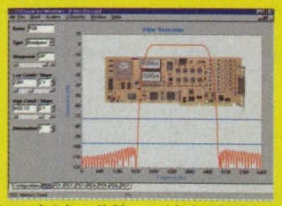

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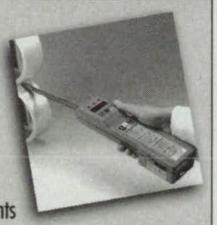

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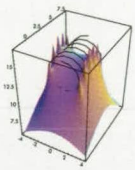

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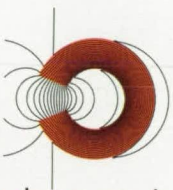

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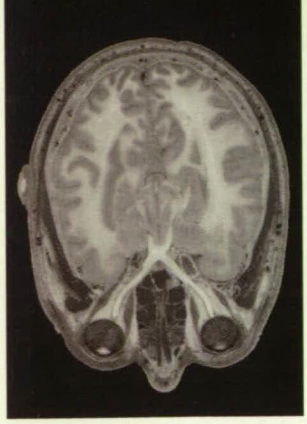

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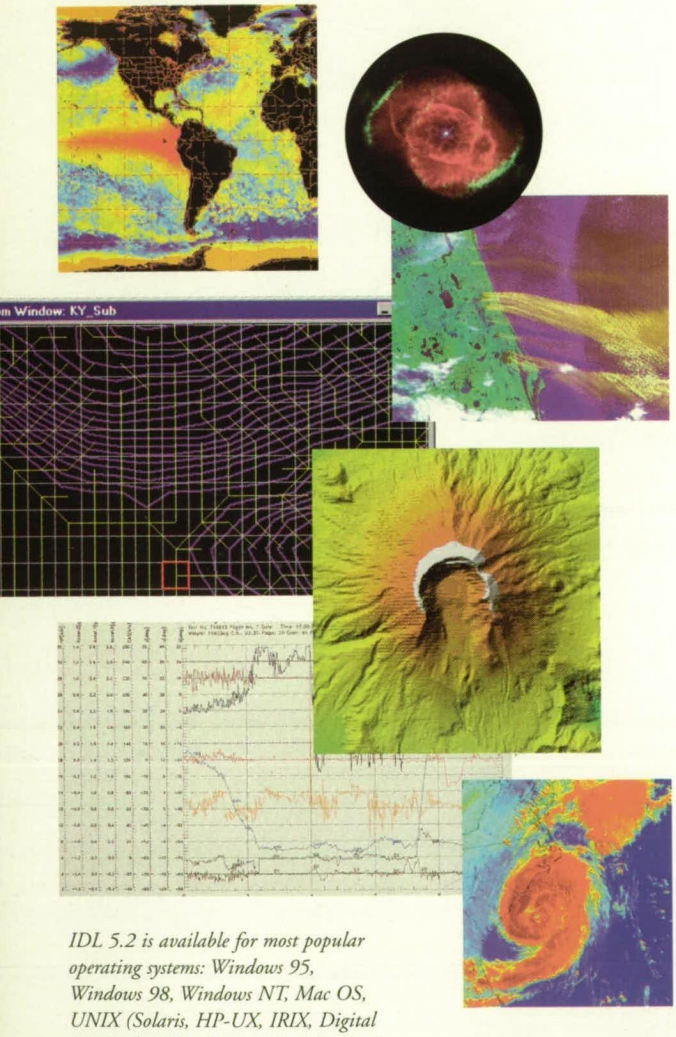

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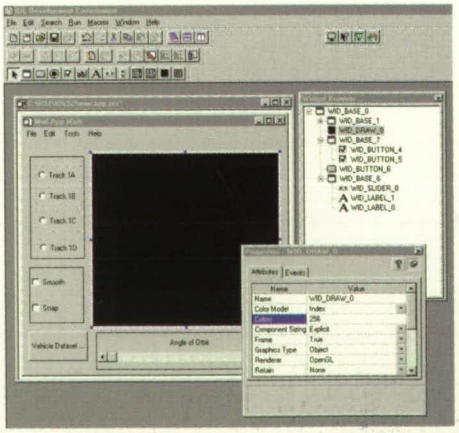

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